EXTERNAL PEER REVIEW OF ECOSYSTEM-BASED FISHERY MANAGEMENT STRATEGY

April 30 – May 3, 2018
Clark Conference Room
NEFSC Woods Hole Laboratory
Woods Hole, MA

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EXECUTIVE SUMMARY

The Ecosystem Based Fishery Management Strategy Review Panel was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council (NEFMC). The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Develop Team and with input from the NEFMC. The Panel consisted of Dr. Lisa Kerr (Chair, Gulf of Maine Research Institute), and Council of Independent Expert reviewers: Dr. Keith Brander (Technical University of Denmark), Dr. Villy Christensen (University of British Columbia), and Dr. Daniel Howell (Institute of Marine Research, Norway). The Panel reviewed the written materials and presentations on the proposed EBFM procedure and addressed nine terms of reference. The terms of reference required the Panel to review the general EBFM approach proposed for implementation by the NEFMC and a simulation tested example of EBFM implementation on Georges Bank.

The Panel recognized the extensive work that went into developing the proposed strategy for implementing EBFM for the NEFMC and in demonstrating the approach in a worked example for the Georges Bank ecosystem. The Panel also appreciated this was a research-track review and that additional work is ongoing to improve aspects of the management procedure. Thus, the feedback and recommendations were intended to improve the EBFM approach. Overall, the Panel concluded that the materials presented during the review represented good progress toward an EBFM procedure, however, further work is needed to refine the approach before it is implemented by the NEFMC. In the following report, areas of strength, areas of concern, and recommendations for improvement of the EBFM procedure are summarized based on the individual reviews by Panel members. The full detail of the individual review of each Panelist is provided in Appendix V (Dr. Keith Brander), Appendix VI (Dr. Villy Christensen), and Appendix VII (Dr. Daniel Howell).

Background

The Ecosystem Based Fishery Management Strategy Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council. This was a research-track review, focused on evaluating the conceptual framework of the proposed EBFM strategy and a worked example of its application to the Georges Bank ecosystem. The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Develop Team and with input from the NEFMC. The review included a simulation study to evaluate the appropriateness of the strawman objectives, operating models, assessment models, reference points, harvest control rules, and performance metrics of the EBFM management procedure. The reviewers were asked to provide feedback on the EBFM strategy and to make recommendations that could improve performance of the EBFM strategy. The goal was not to evaluate the output of the EBFM procedure for use in management specification setting at this stage. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps would include: definition of management objectives by the NEFMC and careful consideration of the potential changes in management units, regulations, and fishery management plans that would be needed to implement EBFM.

Review Panel

The Panel consisted of Dr. Lisa Kerr (Chair), and Council of Independent Expert reviewers: Dr. Keith Brander, Dr. Villy Christensen, and Dr. Daniel Howell. Dr. Lisa Kerr is currently Vice Chair of the NEFMC Science and Statistical Committee and a research scientist with the Gulf of Maine Research Institute (Portland, Maine). Dr. Keith Brander is a Senior Researcher at Technical University of Denmark (Lyngby, Denmark) with a background in integrating ecosystem effects into fisheries assessment and management. Dr. Villy Christensen is a Professor at the University of British Columbia (Vancouver, Canada) specializing in ecosystem modelling. Dr. Daniel Howell is a Fisheries Mathematical Modeller at the Institute of Marine Research, Norway with expertise in multi-species modeling and management strategy evaluation. More information about each panelist's research and scientific expertise can be found at: https://www.nefsc.noaa.gov/program_review/reports2018.html.

As Chair of the Panel, Dr. Kerr facilitated the meeting and made sure that all the terms of reference were reviewed by the Panel. She also led the preparation of the Peer Review Panel Summary Report. Drs. Keith Brander, Villy Christensen, and Daniel Howell served as independent and impartial reviewers. The reviewers each completed independent peer review reports in accordance with the requirements specified in the Statement of Work and terms of reference (Appendix I); reviewers were not required to reach a consensus. Reviewers submitted Individual Peer Review Reports and contributed to the Peer Review Panel Summary Report.

Review Activities

During the review, the NEFMC tasked the Panel with two objectives:

Objective 1: Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC), and

Objective 2: Review the proposed strategy for implementing EBFM on Georges Bank.

Under objective two the Panel was asked to address nine terms of reference (Appendix I):

> *1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.*
>
> *2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.*
>
> *3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.*
>
> *4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.*
>
> *5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).*
>
> *6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.*
>
> *7) Review the structure and application of operating models for Georges Bank.*
>
> *8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.*
>
> *9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.*

Prior to the in-person meeting, the Panel was provided written materials to review that described the EBFM strategy (see Appendix II for a full list). The main document intended for review by the Panel was an overview of the EBFM management procedure entitled "Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study". In addition, a series of background materials were reviewed by the Panel. During the meeting, the EBFM technical team presented on model details and results of model simulations under different harvest control rules (see meeting agenda for a full list of presentations, Appendix III). The team of presenters included Mike Fogarty, Rob Gamble, Sean Lucy, Andy Beet, Geret Depiper (NEFSC scientists), Richard Bell (Nature Conservancy), Amanda Hart (UMass Dartmouth), and Andy Applegate (NEFMC). The review was a public meeting that had several designated times on the agenda for public comment and was open for participation through webinar (Appendix IV). All written materials and presentations were made available at the NEFMC website (https://www.nefsc.noaa.gov/program_review/).

EVALUATION OF TERMS OF REFERENCE

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

The Panel reviewed the written materials and presentations on the methods used to identify ecological production units on the Northeast Shelf of the United States for application in EBFM in the region. The aim was to identify geographically-defined ecological units based on: 1) physical oceanography, 2) hydrographic variables, and 3) biological variables (including primary production, but not upper trophic levels). Multivariate analysis was applied to reduce dimensionality of the data (principal components analysis) and identify clusters of data (disjoint cluster analysis) that represent major ecological production units. This process led to the identification of four ecological production units: 1) Mid-Atlantic Bight, 2) Georges Bank, 3) Western-Central Gulf of Maine, and 4) Scotian Shelf-Eastern Gulf of Maine. These were put forth as the spatial management units that would underpin the EBFM approach in the region. The Panel identified strengths and concerns with the approach and made recommendations for consideration in future work.

Strengths

- Scientifically rigorous method: The Panel recognized that the approach was rigorous and allowed for objective identification of ecological production units (i.e., the data defined the geographic structure).
- Comparable to previous findings: The results of the analysis aligned well with previous approaches to define ecosystem management units using alternative methods (e.g., Clark and Brown 1977, Higgens et al. 1985). This provides support for the ecological production units.

Concerns

- Dynamics of boundaries: One of the concerns of the Panel was that that the boundaries of ecological production units are dynamic and will need to be revisited and updated at some interval. The EBFM technical team should consider an approach for dealing with this concern.
- Connectivity between ecological production units: The EBFM team will have to develop an approach for estimating the exchange of productivity across ecological production units. Many fish stocks will span these boundaries (i.e., migratory species) and this will need to be considered.
- Missing information on upper trophic levels: The approach did not include upper trophic levels (e.g., fish) in the definition of ecological production units. However, given the

desire to have management units that are relatively stable, the focus on physical, oceanographic, and lower trophic data is advisable.

- New management boundaries may create new difficulties: Re-definition of management boundaries may create difficulties in assigning historic fisheries information (both fishery independent and dependent data) and allocating catch shares. This concern will need to be addressed as the EBFM strategy moves forward toward application.

Recommendations

The Panel found the methods for defining ecological production units to be reasonable and recommends that the approach continue to be refined to consider the details of implementing new management units. For example, the Panel recommends consideration of how exchange across ecological production units would be estimated and the appropriate method and timeline for revisiting the boundaries of ecological production units in the future.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

The Panel evaluated the proposed method for estimating ecosystem production potential of ecological production units. The method was a bottom-up approach that was applied to determine fisheries production potential and exploitation for various ecosystem components. The approach utilized information on the: 1) net primary production for two functional groups (nanopicophytoplankton and microphytoplankton), 2) pathway of energy flow in the system, and 3) energy transfer efficiency to estimate total ecosystem production potential. Potential fishery production was then calculated based on applying a 20% exploitation rate on each functional group as described in Moiseev (1994). The approach was illustrated for the Georges Bank Ecological Production Unit. The Panel identified strengths and concerns with the approach and made recommendations for consideration in future work.

Strengths

- Scientifically rigorous method: The basic approach to estimating ecosystem production potential is straight forward and grounded in the scientific literature. In addition, there is good information on lower trophic level productivity in the region to support application of this approach.
- Appropriate for tracking trends: The Panel suggested that the approach is useful for tracking trends in primary production and for understanding how this might impact production at higher trophic levels (considering the lag in transfer of energy through system). This information could be used as a warning sign of changes in the ecosystem and could provide a general context for fisheries management decisions.
- Comparable to previous findings: The initial estimate of Georges Bank fisheries production (220,000 mt) seems to be in the ballpark of estimates produced by others (e.g., 90,000 mt; Link et al. 2008 and 130,000 mt; Collie et al. 2009), although somewhat higher. However, given that the Fogarty et al. estimate includes latent fishery resource production, it is expected to be higher than realized production.

Concerns

- High uncertainty in estimate: The approach of using primary production to estimate fishery production potential is highly uncertain. This estimate was viewed as an appropriate approximation of fishery production; however, the Panel was concerned about the use of this number as a reference point (i.e., a ceiling/overfishing limit). Furthermore, when this number is reported, the associated information on uncertainty should also be reported.
- Alternative approaches: The Panel suggested that other approaches to estimating fishery production (e.g., multi-species surplus production models, Ecopath model) be explored for comparison. Furthermore, different metrics of potential fish production should be considered (e.g., potential fish production vs. fished species production).
- Missing information on upper trophic levels: This method is a bottom-up approach and does not utilize information on upper trophic levels in the estimation of ecosystem production potential. It should be noted that the estimates of fisheries production includes both exploited and non-exploited species.

Recommendations

The Panel viewed the methods for estimating ecosystem productivity for Georges Bank as a useful means of tracking an important and dynamic metric of ecosystem status. However, they did not advise using this for defining limits (i.e., reference point) on fishery removals at this time due to the uncertainty in this method. The Panel suggested that the EBFM technical team explore other methods and metrics of estimating fishery production and continue simulation testing limits on removals defined from multiple approaches to resolve the best approach.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

The Panel evaluated the approach and rationale for specifying fishery functional groups as proposed management units. Fishery functional groups were described as species that are caught together by specified fleet sectors, have similar life history characteristics, and play similar roles in the ecosystem with respect to energy transfer. The approach required characterization of: 1) catch characteristics and targeting practices by fleet, 2) trophic guilds (e.g., benthivore, piscivore, planktivore), and 3) issues of differential risk to species within functional groups based on life history characteristics. The approach is designed to address both technical and biological interactions of species in the definition of the management unit.

Strengths

- Scientifically rigorous method: The approach of using fishery and biological characteristics is reasonable and aspects of this method have been previously published (Garrison and Link 2000, Lucey and Fogarty 2013).
- Addresses technical interactions: This approach enables consideration of biological and technical interactions together in the definition of a management unit. Well-defined

fishery functional groups may help alleviate some of the current issues associated with technical interactions in the mixed stock groundfish fishery.

Concerns

- Appropriateness of fishery functional groups as management units: It is not clear if fishery functional groups are the most appropriate management unit. Further work needs to be done to understand whether grouping by both trophic guilds and fishery characteristics will improve and/or simplify management of the system. These units do not map onto existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge. Furthermore, the appropriateness of the fishery functional group as a management unit will depend on the management objectives which are currently not determined. Therefore, the definition of management units may need to be revisited after final definition of management objectives.
- Dynamics of fishery functional groups: As the availability of fish to the fishery and fisheries practices change, fishery functional groups will change. Due to the definition of these groups being based on historical targeting and catch composition of fisheries in the region, this approach could be inflexible to future changes. The EBFM technical team should consider a method for modification of fishery functional groups to consider future change (e.g., distributional shifts of species or change in fishing behavior). Furthermore, they will need to evaluate the potential changes in fisher behavior associated with the change to EBFM in the region (i.e., quota allocation at the fishery functional group level may change targeting practices).
- Individual species/stock concerns: It will be important to make sure that monitoring and attention to single species will not be lost in this approach. There may be stocks that managers would want to continue to monitor and assess at the individual-level based on management concerns.

Recommendations

The Panel found the definition of fishery functional groups to be a reasonable approach that would enable consideration of biological and technical interactions together in the definition of a management unit. However, the Panel recommends further examination of the appropriateness of this unit for management through simulation testing with a more realistic representation of the fishery functional groups on Georges Bank. The Panel recommends further research into the dynamics of fishery functional groups over time and development of an approach to update management units with changes in the system. In addition, practical considerations of implementing new management units will need to be addressed as these units do not map onto existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

The Panel reviewed a presentation of the strawman management objectives and associated performance metrics for the EBFM procedure. The strawman objectives were used to guide the development of operating models and outputs of the management procedure. The strategic management objectives presented included:

1) maintain/restore sustainable production levels (ecosystem),
2) maintain/restore biomass levels (functional group/species), and
3) maintain/restore functional trophic structure.

A range of operational management objectives were also presented. These included:

1) Ecosystem and community/aggregate fishing mortality and or total catch is below a dynamic threshold,
2) Fishing-related mortality for threatened/endangered/protected species is minimized,
3) Managed and protected species biomass is above established minimum threshold,
4) Maintain ecosystem structure within historical variation recognizing inherent dynamic properties of the system,
5) Maintain habitat productivity and diversity,
6) Habitat structure and function are maintained for exploited species, and
7) Minimize the risk of permanent habitat impacts.

The performance metrics presented were:

1) Functional group status (proportion overfished/depleted)
2) Species status (proportion overfished/depleted)
3) Landings
4) Biomass at species and functional group levels
5) Stability of landings
6) Large fish index (population)
7) Large fish index (landings)
8) Revenue

The presenter indicated that this was a sample list of potential management objectives and ultimately these objectives would be determined by the NEFMC through outreach and engagement with stakeholders. The presentation also discussed the Magnuson-Stevens Act and outlined how EBFM is consistent with new National Standard 1 guidelines (i.e., NS 1 would allow for using an aggregate approach to estimate the maximum sustainable yield of a fishery).

Strengths

- Reasonable approach: The strawman management objectives were reasonable, high level objectives, but will need to be refined for operational use. The expectation is that these will be refined and expanded upon through the stakeholder engagement process.

Concerns

- Limited in scope: The strawman objectives should not limit the full scope of objectives considered in the MSE. For example, economic and social management objectives should be considered more fully.

- Single species metrics: Another concern is that the only metric of single species stock status being tracked is reduction below 20% of unfished biomass (B_{lim}). This provides information on reduced stock reproduction potential, but does not give information on reduced yield potential. The fraction of stocks falling below the higher trigger point of the ramp-down harvest control rule (point at which fishing is reduced) should be tracked as a metric as well.
- Strawman objectives limit model structure: The Panel notes that the strawman objectives have, in part, defined the metrics that are output from the current MSE framework. As the management objectives evolve, there may be a need to revisit the structure of the model and HCRs as management objectives will need quantifiable outputs to track performance from the model. Furthermore, some of the operational objectives presented (i.e. habitat objectives) are not integrated into the MSE or linked to performance tracking.
- Strategic and operational objectives not linked: When management objectives are finalized, there should be a clear linkage made between strategic objectives, operational objectives and the associated performance metrics.

Recommendations

The Panel viewed the strawman management objectives as a reasonable starting point for the EBFM procedure, however, the Panel expects that these will be refined and expanded upon in the future through the stakeholder engagement process. The Panel recommends that additional objectives are explored based on input from stakeholder engagement, these should include biological, economic, and social objectives. Expansion of management objectives may require iteration of the model to accommodate performance measures which are not currently quantified in the current structure.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

The Panel reviewed the proposed management reference points for the EBFM management procedure, which included: 1) an overall catch cap at the ecological production unit level conditioned on system productivity, 2) ceilings on catch for each fishery functional group (defining overfishing) conditioned on aggregate properties, and 3) biomass floors at the single species level (defining overfished conditions). The definition of the ecosystem overfishing limit was proposed to be based on the dynamic 'carrying capacity' of the ecosystem as a function of production at the base of the food web. The methods for estimating this value were reviewed under ToR 2. It was not clear how the ceilings on catch for fishery functional groups would be calculated, just that their sum would not exceed the overall cap. Biomass floors were proposed to be calculated at either the fishery functional group (biomass of fishery functional group not to fall below 20% of unfished biomass) or individual species level (biomass of any species not to fall below 20% of unfished biomass).

Strengths

- Reasonable approach: The Panel viewed the proposed approach to define management reference points (i.e., floors and ceilings) as a reasonable approach, however there was substantial concern regarding the details of how reference points would be calculated. The implementation of these reference points will require simulation testing.

Concerns

- Definition of biomass floors: The Panel had concerns about biomass floors for single species and how are these will be defined (e.g., the use of unfished biomass to define the limit, and what percentage of unfished biomass should be used as a limit [i.e. should all species be at 20% ?]).
- Definition of ecosystem ceiling: The concept of the overall catch cap is useful, but the Panel was concerned about using primary production as the basis for limiting fishing and it was unclear how the ecosystem ceiling would be applied in fisheries decision making. In theory it seems like the catch cap should not be breached, however, there was concern that this could be risky if this value is viewed as a target. Further work needs to be done to define the role of the ecosystem ceiling in management and the corresponding action that would occur when the ceiling is breached (HCRs need to specify this). The simulations only included action when biomass dropped below floors.
- Definition of fishery functional group ceiling: There is a need to clarify the calculation of the catch cap for fishery functional groups. What was proposed in the general description of the management procedure and what was implemented in the worked example for Georges Bank (sum of single species MSYs) were different approaches. If the MSY approach is pursued for this purpose, the MSY for fishery functional groups, should be calculated based on a multispecies model (not sum of single species MSY).
- Dynamics of reference points: The Panel was concerned whether these reference points will be responsive to ecosystem change. This concern is not specific to an EBFM approach, but the EBFM team should carefully consider the data used in estimation, how linked reference points will be to historic production, and how often values will be re-estimated to reflect current conditions.

Recommendations

The Panel approved of the general approach of defining floors and ceilings for use as reference points in an EBFM procedure. However, there was substantial concern about how these numbers would be estimated and applied in operational management. In addition, the Panel recommends further examination of how ceilings will be used in a real-world application (e.g., what action would be taken when an ecosystem or fishery functional group ceiling is breached).

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

The Panel reviewed potential harvest control rules embodying the proposed floors and ceilings approach to management whereby overfishing is determined at the fishery functional group level and the overfished status is determined either at the fishery functional group or individual species level. Two main forms of harvest control rules were explored: 1) threshold exploitation, whereby exploitation rate is constant until a threshold biomass level is reached (i.e., a fishery functional group or individual species floor), and 2) ramp-down exploitation whereby exploitation rate ramps down (step-wise approach) when a trigger point in reached and ceases then threshold is reached (i.e., fishery functional group or individual species floor). In addition, scenarios were examined which provided additional protection for vulnerable species (e.g., skates and sharks). For each scenario, system-based exploitation rates were simulated ranging from 0.05 to 0.4. The evaluation used performance metrics for revenue, functional group status, species status, landings, biomass, stability of landings, the proportion of large fish in the population, and the proportion of large fish in the landings. Overall, ramp-down harvest control rules, structured with a reduction in exploitation prior to declines in biomass approaching overfished, performed better than threshold harvest control rules. Early intervention preserved resilience as measured by species diversity and representation of large fish in system.

Strengths

- Reasonable approach: If reasonable floors and ceilings can be defined, the Panel indicated that the shapes of HCRs investigated make sense. The Panel expects that the current HCRs would be expanded upon and refined as the approach develops.

Concerns

- Definition of triggers and thresholds: The Panel was concerned about the estimation of reference points that define the triggers and threshold within the HCRs (see ToR 5). How to calculate reference points in an operational manner remains a serious concern.
- Lack of status quo comparison: The EBFM technical team has built the EBFM MSE for the purpose of testing fishery functional group HCRs. However, there is no comparison of the performance of this multispecies approach to the current single species management.
- Form of harvest control rule: In general, the form of HCRs investigated was reasonable, however, the use of step functions within the ramp-down HCR was not supported by the Panel. The use of a step-functions can have unintended consequences when applied in management, with small changes in an assessment producing large changes in quotas. This places stress on the reliability of the assessment and can lead to implementation difficulties. The Panel recommends that step functions within HCRs be replaced with a slope.

- Ramp-down trigger: The Panel recommends further consideration of the appropriate trigger point (currently 40% B_0) for use in the ramp-down harvest control rules through simulation testing.
- Hybrid approach: The Panel suggested consideration of a hybrid approach whereby in addition to overall quotas for a fishery group there is a more specific constraint on one (or several) key species (not necessarily only related to life history vulnerability).
- Simulation testing: The Panel noted that HCRs were only tested using the Hydra operating model. Ideally, HCRs would be tested using multiple operating models (e.g., Kraken, Atlantis).

Recommendations

The Panel viewed the proposed harvest control rules as a reasonable starting point, provided the stepwise changes in fishing level are removed from the ramp-down HCR, but recommends that more harvest control rules are explored and that alternative control rules are simulation tested and compared to the performance of current single species harvest strategies. The Panel was concerned about the estimation of reference points (floors, ceilings, and trigger points) within the HCRs and recommends this as an area requiring more development and simulation testing.

ToR 7: Review the structure and application of operating models for Georges Bank.

The Panel reviewed the written materials and presentations on two operating models for Georges Bank: 1) Hydra, a multispecies-multifleet length-structured simulation model; Gaichas et al. 2017) and 2) Kraken, a multispecies production model; Gamble and Link 2009.

Hydra is a ten species, size-structured model, implemented for three fleets: demersal trawl, fixed gear (longline and gillnet), and pelagic trawl. Hydra traces population trajectories of a multispecies assemblage as a function of size, growth, recruitment and survival. Hydra was applied as a basis for testing the EBFM management procedure. Hydra includes technical and biological interactions as the fish species have size structure, which determines interactions and catchabilities.

Kraken is a ten species production model that requires biomass/abundance time series or survey index and a catch time series as inputs. The Kraken surplus production function acts as an operating model, simulating biomasses for 10 species. In the worked example, Kraken was applied for the purpose of portfolio analysis. The portfolio approach involves the application of financial portfolio theory to multispecies fishery management. The approach allows economic risks and returns to be calculated across varying combinations of species' harvest and allows for simulating an optimal harvest strategy for the system. Kraken was also used as the basis for assessing the use of catch ceilings which limit total removals from the ecosystem in the EBFM procedure (work by A. Hart).

Strengths

- Hydra model: The Hydra model provides a good basic structure for this purpose, combining detail and potential realism with moderate run times. This is a peer-reviewed, published model (Gaichas et al. 2017).
- Kraken model: The Kraken model is simpler in form and thus enables different applications due to the speed of model runs (e.g., portfolio analysis).
- Alternative models: There are two potential operating models (Hydra and Kraken). It is good practice to have multiple operating models.

Concerns

- Hydra scope and structure: The Panel suggests that the EBFM technical team evaluate the appropriate number of species for the operating models and expand on the fleet structure to ensure they are able to emulate realistic biological and technical interactions. It is not necessary that the model completely matches the "real world", but it may be necessary to increase the level of detail in the model to approximate population and fishery dynamics for robust testing of HCRs. Another concern with the Hydra model structure is whether the model is stable when moving away from the base scenario (e.g., is there a tendency for populations to crash in the model?).
- Hydra trophic interactions: Ideally, the key food components for species within the model should be fully modelled. If this is not possible, then care should be taken with modeling "other food", giving as much realism as possible and checking for model sensitivity to this input. In addition, the trophic interactions in the model do not include interactions at early life history stages and it would be worthwhile for the team to consider how important this may be to the realism of the model.
- Hydra stock recruit relationships: The Panel questioned the form and range of S-R models included in Hydra. The Panel was concerned with the use of a hockey stick form, as it tends to produce lower compensation than Beverton and Holt models at low spawning stock biomass. On the other hand, the range of curves explored were all to the left of the fitted function, which will provide stronger compensation and perhaps spurious robustness to the effect of fishing in the model (i.e., making it hard to fish-down stocks). In addition, the variability included on the recruitment functions are currently lognormal. This may be too restrictive for some stocks, such as haddock where other methods may be better at approximating erratic high recruitment. The Panel recommends exploring different forms and a balanced representation of possible S-R curves around the fitted function.
- Further development of Kraken model: The Panel suggests that further development of the Kraken model is needed, including work to evaluate the appropriate number of species in the model and incorporation of more realistic fleet structure, as well as simulation testing of the performance of the operating model.
- Hydra and Kraken model performance uncertain: The Hydra and Kraken models seem appropriate in structure, but realizations of operating models have not been checked. There is a need to evaluate the model against real world observations/trends to demonstrate that these models can produce credible results (e.g., when model is informed

by high catch levels on the order of historic catch does the model demonstrate a decline for those species).

- Range of model complexity: There are trade-offs in modelling between providing a detailed representation of ecosystem dynamics as compared to a simple representation that captures the dynamics that matter for a specific question. The Hydra and Kraken simulations could be regarded as an example of each. It would be worthwhile to explore other models that varying in their level of detail and complexity (e.g., models that include the full size spectrum of fish life histories and therefore take account of early life interactions).
- Application of alternative operating models: Kraken was used for the portfolio analysis and testing ceilings and Hydra was used for harvest control rule testing. If feasible, the operating models should each be utilized as a basis for the portfolio analysis as well as testing of harvest control rules. However, it is important to note that the two models are not truly independent as Kraken was tuned to results from Hydra. Ideally, the two models would be independent and applied for each purpose. Furthermore, additional alternative operating models could be utilized that include greater complexity (e.g., Atlantis model once update is complete and ecopath model).

Recommendations

The Panel viewed the development of two multispecies operating models (Hydra and Kraken) with varying levels of complexity as good practice for testing aspects of the EBFM procedure. The Panel recommends specific areas for improvement for each model. The biggest concern is the need to evaluate the model output against real world observations/trends to demonstrate that these models can produce credible results. The Panel recommends further work evaluating the output of both operating models (Hydra and Kraken) to evaluate how well they can approximate current and past stock dynamics given similar fishing conditions. The Panel also recommends that the operating models should be used for cross purposes if possible (i.e., each be applied for harvest control rule testing and portfolio analysis). In addition, the Panel recommends that additional operating models for the Georges Bank ecosystem (e.g., the Atlantis model which is being updated and Ecopath model that is in development) be considered as a basis for simulation testing.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

During the meeting, the Panel reviewed a presentation on ecosystem assessment models and their required data sources. The proposed alternative assessment methods included a: 1) model-free simulated survey index, 2) multispecies production model, and 3) multispecies delay-difference model. The models require biomass and catch data as inputs. The proposed models range in their complexity, enabling evaluation of whether simpler assessment models can capture population dynamics of a complex underlying model. A modeling efficiency index used in evaluating the performance of the stock assessment. The performance of assessment models was tested with white noise only, however, in the future, bias can be added to performance testing. Simulation testing revealed that the more complex delay-difference model performed similarly to the simpler production model.

Strengths

- Comparison of multiple models: The comparison of multiple alternative models is a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model.

Concerns

- Multispecies vs. single species assessment models: The Panel noted that multispecies assessment models were examined, but no comparison was conducted between the performance of multispecies and single species assessments.
- Testing alternative assessments and HCRs: The testing of alternative assessment methods (e.g. multispecies assessments) should be conducted separately from testing of alternative HCRs.

Recommendations

The Panel viewed the comparison of alternative models as a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model. The Panel recommends that the alternative multispecies assessment models be compared to single species models. Furthermore, the Panel recommends that evaluation of new assessment methods and new harvest control rules not be conducted simultaneously, as this will make it difficult to evaluate what was causing any successes or failures in the simulated management.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

The Panel reviewed written materials and presentations on simulation tests and the performance of the proposed management procedure as implemented for the Georges Bank example. The Panel was instructed that performance was not being reviewed for the context of implementation for management, but to evaluate the approach.

Strengths

- Reasonable performance: The Panel noted that the initial results presented during the review seem reasonable in terms of performance based on their response to different forms of harvest control rule, although more critical evaluation of performance is required.
- Evaluation of ceilings: The Panel found the simulation testing of a range of ceilings and their impact on the performance of the EBFM procedure to be very useful and this work should be continued (A. Hart presentation).

Concerns

- Limited simulation testing: The Panel suggested that a broader representation of simulation results is needed to fully evaluate the performance of HCRs in the future. This should include a status quo comparison where the current single species management approach is approximated for comparison to the EBFM approach. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance. More generally, wherever there is a simplification (e.g., thresholds, trigger points, global exploitation rates, FFG structure) in the model, the Panel recommends that the effects of adding realism are investigated for each simplification separately. It may be that some of the current simplifications are justified, increasing speed and robustness without harming accuracy, but this needs to be tested.
- Presentation of HCR testing results: It is important to note that the performance metrics shown in radar plots were normalized to the highest value across simulations (i.e., highest value was defined as 100%) which can lead to potential misinterpretations of performance. Further work resolving management objectives with stakeholders may help to define the desire performance of the system and allow for performance to be evaluated relative to these values. The box plots will need some refinement for clarity (e.g., labels, similar scales, titles, etc.) in final reporting.
- Exploitation rates in HCR testing: In the current presentation of results the initial global exploitation rates used in the simulated scenario were shown, but not the realized exploitation levels. Information on realized F and realized F/nominal F would help identify the degree to which catch in a given FFG was being reduced by the single species protections within the HCRs.
- Alternative performance metrics: The current overfished metric tracks the fraction of time spent in a depleted state. This is problematic as it is influenced by the recruitment at low stock sizes. Alternatively, this could also be assessed by counting how many stocks crash at least once in any given 10-year reporting period.
- Portfolio analysis It was unclear how the portfolio analysis will be used in the EBFM procedure. Further linkage and description of the role portfolio analysis could play is needed.

Recommendations

The Panel noted that the initial results presented during the review seem reasonable in terms of performance, however, the performance of the EBFM procedure cannot be fully evaluated at this stage due the preliminary state of the work (i.e., many decisions need to be finalized both on model details and management objectives) and the limited nature of simulations run. The Panel suggested that a broader representation of simulation results is needed, including a comparison of EBFM to single species management, to fully evaluate the performance of the EBFM procedure. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance and the impact of model simplifications should be critically evaluated. The simulated output is an example of how performance would be evaluated, and the Panel provided specific suggestions on the presentation of results.

CONCLUSIONS

The Panel recognized the extensive work that went into developing the proposed strategy for implementing EBFM for the NEFMC and in demonstrating the approach in a worked example for the Georges Bank ecosystem. The Panel also appreciated this was a research-track review and that additional work is ongoing to improve aspects of the management procedure. Thus, the feedback and recommendations were intended to improve the EBFM approach. This summary report synthesized individual Panelists' feedback on areas of strength, areas of concern, and recommendations for improvement of the EBFM procedure. For the full details of the individual review of each Panelist see Appendix V (Dr. Keith Brander), Appendix VI (Dr. Villy Christensen), and Appendix VII (Dr. Daniel Howell).

Overall, the Panel concluded that the materials presented during the review represented good progress toward an EBFM procedure, however, further work is needed to refine the approach before it is implemented by the NEFMC. Below is a summary of feedback and recommendations for each term of reference.

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.
The Panel found the methods for defining ecological production units to be reasonable and recommends that the approach continue to be refined to consider the details of implementing new management units. For example, the Panel recommends consideration of how exchange across ecological production units would be estimated and the appropriate method and timeline for revisiting the boundaries of ecological production units in the future.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.
The Panel viewed the methods for estimating ecosystem productivity for Georges Bank as a useful means of tracking an important and dynamic metric of ecosystem status. However, they did not advise using this for defining limits (i.e., reference point) on fishery removals at this time due to the uncertainty in this estimate. The Panel suggested that the EBFM technical team explore other methods and metrics of estimating fishery production and continue simulation testing limits on removals defined from multiple approaches to resolve the best approach.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.
The Panel found the definition of fishery functional groups to be a reasonable approach that would enable consideration of biological and technical interactions together in the definition of a management unit. However, the Panel recommends further examination of the appropriateness of this unit for management through simulation testing with a more realistic representation of the fishery functional groups on Georges Bank. The Panel recommends further research into the dynamics of fishery functional groups over time and development of an approach to update management units with changes in the system. In addition, practical considerations of implementing new management units will need to be addressed as these units do not map onto

existing management units (single-species stocks) or the scale at which harvest is allocated (sectors), and the transition may be a challenge.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.
The Panel viewed the strawman management objectives as a reasonable starting point for the EBFM procedure; however, the Panel expects these will be refined and expanded upon in the future through the stakeholder engagement process. The Panel recommends additional objectives are explored based on input from stakeholder engagement, these should include biological, economic, and social objectives. Expansion of management objectives may require iteration of the model to accommodate performance measures which are not currently quantified in the current structure.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management.
The Panel approved the general approach of defining floors and ceilings for use as reference points in an EBFM procedure. However, there was substantial concern about how these numbers would be estimated and applied in operational management. In addition, the Panel recommends further examination of how ceilings will be used in a real-world application (e.g., what action would be taken when an ecosystem or fishery functional group ceiling is breached).

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.
The Panel viewed the proposed harvest control rules as a reasonable starting point, provided the stepwise changes in fishing level are removed from the ramp-down HCR, but recommends that more harvest control rules are explored and that alternative control rules are simulation tested and compared to the performance of current single species harvest strategies. The Panel was concerned about the estimation of reference points (floors, ceilings, and trigger points) within the HCRs and recommends this as an area requiring more development and simulation testing.

ToR 7: Review the structure and application of operating models for Georges Bank.
The Panel viewed the development of two multispecies operating models (Hydra and Kraken) with varying levels of complexity as good practice for testing aspects of the EBFM procedure. The Panel recommends specific areas for improvement for each model. The biggest concern is the need to evaluate the model output against real world observations/trends to demonstrate that these models can produce credible results. The Panel recommends further work evaluating the output of both operating models (Hydra and Kraken) to evaluate how well they can approximate current and past stock dynamics given similar fishing conditions. The Panel also recommends that the operating models should be used for cross purposes if possible (i.e., each be applied for harvest control rule testing and portfolio analysis). In addition, the Panel recommends that additional operating models for the Georges Bank ecosystem (e.g., the Atlantis model which is being updated and Ecopath model that is in development) be considered as a basis for simulation testing.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

The Panel viewed the comparison of alternative models as a good approach to understand the appropriate model and level of complexity for the ecosystem assessment model. The Panel recommends that the alternative multispecies assessment models be compared to single species models. Furthermore, the Panel recommends conducting the evaluation of new assessment methods and new harvest control rules separately, as this will make it easier to evaluate what was causing any successes or failures in the simulated scenario.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

The Panel noted that the initial results presented during the review seem reasonable in terms of performance, however, the performance of the EBFM procedure cannot be fully evaluated at this stage due the preliminary state of the work (i.e., many decisions need to be finalized both on model details and management objectives) and the limited nature of simulations run. The Panel suggested that a broader representation of simulation results is needed, including a comparison of EBFM to single species management, to fully evaluate the performance of the EBFM procedure. Furthermore, one factor within the EBFM procedure should be changed at a time to be able to fully evaluate its impacts on performance and the impact of model simplifications should be critically evaluated. The simulated output is an example of how performance would be evaluated, and the Panel provided specific suggestions on the presentation of results.

APPENDIX I: Terms of Reference

Final Terms of Reference
Ecosystem Based Fishery Management Strategy Review
April 30-May 3, 2018
NOAA Fisheries/Clark Conference Room
Woods Hole MA

Objective 1

Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the New England Fishery Management Council. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC strawman management objectives as well as evaluate a worked example intended to simulate the performance of the EBFM procedure. (The strawman objectives were used to develop the EBFM strategy and framework; final objectives will be developed and approved by the NEFMC at a later date.)

The reviewers will be asked to provide recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a SAW/SARC assessment review).

The review will encompass the EBFM procedure, the potential operating models used to test the procedure, and a worked example of the relative performance of the EBFM procedure for providing quota advice as they pertain to fisheries management of Georges Bank fisheries.

If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group OFLs, potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Objective 2

Review the proposed strategy for implementing EBFM on Georges Bank

Terms of Reference

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

APPENDIX II: Documents for Review

Main Review Document

NEFSC Fishery Ecosystem Dynamics Assessment Branch. 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. April 20-May 2, 2018, Woods Hole, MA. https://www.nefsc.noaa.gov/program_review/docs/Georges%20Bank%20EBFM%20Summary%20Document.pdf.

Background Documents for Review

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for Prototype Georges Bank, Fishery Ecosystem Plan. Catch Advice Framework, a Worked Example #2. New England Fishery Management Council. September 26-28, 2017. http://s3.amazonaws.com/nefmc.org/2_A-Framework-for-Proividing-Catch-Advice-for-a-Prototype-Georges-Bank-FEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for a Fishery Ecosystem Plan (FEP). New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. DRAFT: Example application of operation models for Georges Bank ecosystem production unit (EPU) strategy evaluation. New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-3.-Example-application-of-operating-models-for-Georges-Bank-ecosystem.pdf.

Fogarty, M. J., Overholtz, W. J., Link, J. S. 2012. Aggregate surplus production models for demersal fisher resources of the Gulf of Maine. Marine Ecology Progress Series, 459:247-258. https://www.nefsc.noaa.gov/program_review/docs/b4-fogarty%20et%20al%20MEPS.pdf.

Gaichas, S., Gamble, R., Fogarty, M., Benoît, H., Essington, T., Fu, C., Koen-Alonso, M., Link., J. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Marine Ecology Progress Series, 459:275-292. https://www.nefsc.noaa.gov/program_review/docs/b5-Gaichas%20et%20al%20MEPS.pdf.

Gamble, R. J., Link, J. S. 2012. Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community. Marine Ecology Progress Series, 459:259-274. https://www.nefsc.noaa.gov/program_review/docs/b-6Gamble%20and%20Link%20MEPS.pdf.

Hennemuth, R. C., Rothschild, B. J., Anderson, L. G., Kund, Jr., W. A. 1980. Overview Document of the Northeast Fisher Management Task Force, Phase 1. NOAA Technical Memorandum NMFS-F/NEC-1. October 1980. https://www.nefsc.noaa.gov/program_review/docs/b3-tm-1-hennemuith.pdf.

Link, J. S., Gamble, R. J., Fogarty, M. J. 2011. An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards

Ecosystem-based Fisheries Management. Northeast Fisheries Science Center Reference Document 11-23. October 2011. https://www.nefsc.noaa.gov/program_review/docs/b2-crd-1123.pdf.

Lucey, S. M., Cook, A. M., Boldt, J. L., Link, J. S., Essington, T. E., Miller, T. J. 2012. Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems. Marine Ecology Progress Series, 469:219-229. https://www.nefsc.noaa.gov/program_review/docs/b-7Lucey%20et%20al%20MEPS.pdf.

NEFMC Scientific and Statistical Committee. 2010. White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council. October 2010. https://www.nefsc.noaa.gov/program_review/docs/b1NEFMC%20EBFM%20White%20Paper_report_15%20oct%202010.pdf

APPENDIX III: Meeting Agenda

Agenda, Documentation, and Presentations for 2018 Ecosystem Based Fishery Management (EBFM) Strategy Review

Date	***Time***	***Topic and Related Documents***	***Presenter/Lead***	***Theme Area***
Monday April 30	9:00 AM	**Welcome and Objectives for the Review** Background Documents **Ecosystem-Based Fishery Management Strategy Georges Bank Prototype Study Summary Document** **White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council (2010)** **An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management** **Overview of the Northeast Fishery Management Task Force Phase 1 (1980)** **Aggregate surplus production models for demersal fishery resources of the Gulf of Maine** **Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation** **Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community** **Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems**	Jon Hare *NEFSC Science and Research Director* Mike Simpkins *Resource Evaluation and Assessment Division Chief*	
	9:15 AM	**Logistics**	Robert Gamble, NEFSC	
	9:30 AM	**NEFMC Ecosystem-Based Fisheries Management Plan Development Team** Background Documents **A Framework for Providing Catch Advice for a Prototype Georges Bank Fishery Ecosystem Plan** **A Framework for Providing Catch Advice For a Fishery Ecosystem Plan** **DRAFT: Example application of operating models for Georges Bank ecosystem production unit (EPU) strategy evaluation**	**Andrew Applegate**, NEFMC	

	10:00 AM	**Background and Overview of Proposed Management Procedure**	**Michael Fogarty**, NEFSC	
		10:30 Break		
	11:00 AM	**Defining Ecological Production Units**	**Robert Gamble**, NEFSC	TOR 1
	11:30 AM	**Ecosystem Production Potential**	**Michael Fogarty**, NEFSC Kimberly Hyde, NEFSC	TOR 2
		12:00 Lunch		
	1:30 PM	**Defining Fishery Functional Groups**	**Sean Lucey**, NEFSC Mike Fogarty, NEFSC	TOR 3
	2:00 PM	**Strawman Management Objectives and Performance Metrics**	**Richard Bell** The Nature Conservancy	TOR 4
	2:30 PM	**Ecosystem-Based Reference Points**	**Michael Fogarty**NEFSC	TOR 5
		3:00 Break		
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Tuesday May 1	9:00 AM	**Harvest Control Rules**	**Mike Fogarty**, NEFSC	TOR 6
	9:30 AM	**Structure and Application of Operating Models -- Part 1 Hydra**	**Andy Beet**, NEFSC Mike Fogarty, NEFSC	TOR 7
		10:30 Break		
	11:00 AM	**Structure and Application of Operating Models -- Part 2 Kraken**	**Robert Gamble**, NEFSC Geret DePiper, NEFSC	TOR 7
		12:00 Lunch		

	1:30 PM	**Structure and Application of Assessment Models**	**Mike Fogarty**, NEFSC	TOR 8
	2:00 PM	**Simulation Tests and Performance Management Procedure -- Part 1 Hydra**	Andy Beet, NEFSC **Michael Fogarty**, NEFSC	TOR 9
	3:00 PM Break			
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Wednesday May 2	9:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 1 Hydra, continued**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 9
	10:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken**	**Amanda Hart**, UMASS Dartmouth **Geret Depiper**, NEFSC Robert Gamble, NEFSC	TOR 9
	10:30 Break			
	11:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken,continued**	Geret Depiper, NEFSC Robert Gamble, NEFSC Amanda Hart, UMASS Dartmouth	TOR 9
	12:00 Lunch			
	1:30 PM	**Open Question Period**		
	3:00 PM Break			
	3:30 PM	**Public Comment Period**		
	4:30 PM	**Review Panel Discussion (private)**		
Thursday May 3	9:00 AM	**Review Panel Report Writing (private)**		

APPENDIX IV: Meeting Participants

Name	Affiliation	E-Mail
Robert Gamble	NEFSC/EDAB	robert.gamble@noaa.gov
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External Peer Review of Ecosystem-Based Fishery Management Strategy

April 30 – May 3, 2018

Clark Conference Room
NEFSC Woods Hole Laboratory
Woods Hole, MA

Individual Peer Review Report prepared for the Center for Independent Experts

by
Dr. Keith Brander

DTU Aqua, Technical University of Denmark, Kongens Lyngby, Denmark

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EXECUTIVE SUMMARY

The Panel were given a very detailed and cogent series of presentations on the proposed ecosystem-based fisheries management (EBFM) strategy and conceptual framework that aims to provide information needed for fisheries management by the New England Fisheries Management Council (NEFMC) The standard of the work described was excellent and gives a very good basis for moving forward to the next stage in implementing EBFM. Specifically, the proposed Ecological Production Units (EPU) are founded on consistent and objective methods and appropriate data to define ecological regions for which integrated management plans can be developed. The proposed Fishery Functional Groups (FFGs) will help to address problems arising from technical and biological interactions in the mixed fishery and to reduce the cost and complexity of management. However, they will not solve these problems on their own and are best regarded as a starting point from which to test and improve.

The EBFM strategy performance framework that we were tasked to evaluate includes objectives, management strategy (including harvest control rules), simulation (operating) models and performance statistics. The framework employs state-of-the-art methods and builds on the impressive body of knowledge about the marine ecosystems, productivity, fisheries and history of Georges Bank and the NEFMC area. The simulated stock assessments should be compared with current single species stock assessments as a step towards carrying out full management strategy evaluation, bearing in mind that the first step towards EBFM is to show that it is an improvement on current management.

The development of EBFM for the area is framed by national regulations and is to a greater or lesser extent constrained by the status quo in terms of current structure of fisheries enterprises and fish stocks but also other social, economic and conservation interests. The strategy performance framework and the ‘‘strawman” objectives are designed principally to maintain high biomass productivity of a range of species and sufficient biomass of species that may become overfished. Extensions to the framework (and its simulation models) or evaluation of other models with different structures would help to explore a wider range of objectives, and would also provide comparisons to highlight the strengths and weaknesses of different simulation models and approaches. In particular I would suggest the use of other models that include the full-size spectrum of fish life histories, and therefore take account of early life interactions. For example, a recently published size-based model of the Northeast (NE)US shelf fisheries ecosystem explores ecosystem-level efficiency of trade-offs between yield and conservation impacts using a size-based 24 species model and concludes that gains in both yields and conservation are possible.

BACKGROUND

The Ecosystem Based Fishery Management Strategy Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council. This was a research-track review, focused on evaluating the conceptual framework of the proposed EBFM strategy and a worked example of its application to the Georges Bank ecosystem. The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Develop Team, and with input from the NEFMC. The review included a simulation study to evaluate the appropriateness of the strawman objectives, operating models, assessment models, reference points, harvest control rules, and performance metrics of the EBFM management procedure. The reviewers were asked to provide feedback on the EBFM strategy and to make recommendations that could improve performance of the EBFM strategy. The goal was not to evaluate the output of the EBFM procedure for use in management specification setting at this stage. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group overfishing limits (OFLs), potential changes in management units, etc.

REVIEW PANEL

The Panel consisted of Dr. Lisa Kerr (Chair), and Center for Independent Experts (CIE) reviewers: Dr. Keith Brander, Dr. Villy Christensen, and Dr. Daniel Howell. Dr. Lisa Kerr is currently Vice Chair of the NEFMC Science and Statistical Committee and a research scientist with the Gulf of Maine Research Institute, Portland, Maine. Dr. Keith Brander is a Senior Researcher at Technical University of Denmark, Lyngby, Denmark, with a background in integrating ecosystem effects into fisheries assessment and management. Dr. Villy Christensen is a Professor the University of British Columbia specializing in ecosystem modelling. Dr. Daniel Howell is a Fisheries Mathematical Modeller at the Institute of Marine Research, Bergen ,,Norway, with expertise in multi-species modeling and management strategy evaluation. More information about each panelist's research and scientific expertise can be found at: https://www.nefsc.noaa.gov/program_review/reports2018.html.

As Chair of the Panel, Dr. Kerr facilitated the meeting and made sure that all the terms of reference were reviewed by the Panel. She also led the preparation of the Peer Review Panel Summary Report. Drs. Keith Brander, Villy Christensen, and Daniel Howell served as independent and impartial reviewers. The reviewers each completed independent peer review reports in accordance with the requirements specified in the Statement of Work and terms of reference (Appendix A), in adherence with the required formatting and content guidelines; reviewers were not required to reach a consensus. Reviewers submitted Individual Peer Review Reports and contributed to the Peer Review Panel Summary Report.

REVIEW ACTIVITIES

During the review, the NEFMC tasked the Panel with two objectives: 1) review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC), and 2) review the proposed strategy for implementing EBFM on Georges Bank. Under objective two, the Panel was asked to address nine terms of reference (Appendix A):

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.
2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.
3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.
4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.
5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).
6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.
7) Review the structure and application of operating models for Georges Bank.
8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.
9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

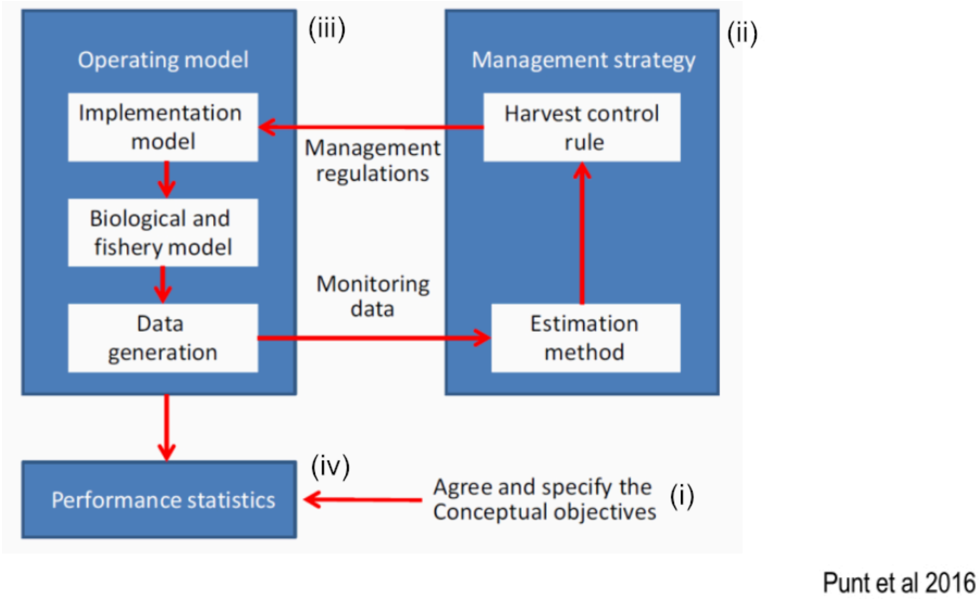
Prior to the in-person meeting, the Panel was provided written materials to review describing the EBFM strategy. During the meeting, the NEFSC EBFM technical team and NEFMC EBFM Plan Development Team (PDT) (including Drs. Mike Fogarty, Rob Gamble, Sean Lucy, Andy Beet, Andy Applegate) presented on model details and results of model simulations under different harvest control rules (see meeting agenda, Appendix B). The review was a public meeting that had several designated times on the agenda for public comment and was open for participation through webinar (Appendix C). All written materials and presentations were made available at the NEFMC website (https://www.nefsc.noaa.gov/program_review/).

INDEPENDENT EVALUATION OF THE NINE TERMS OF REFERENCE

Preamble on interdependence of objectives and tools

The stated goal of our review is “to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the NEFMC”. The strategy and framework (Figure 1) includes (i) objectives (“strawman objectives” since they are yet to be decided by NEFMC), (ii) a management strategy to achieve those objectives, (iii) the “operating model” (or multispecies fishery simulation model), which is “in this case a multi-model suite that can include empirical approaches as well as simulation models” to represents the fisheries system being managed, and (iv) performance statistics.

Figure 1: Strategy and framework. Performance statistics relate the output of the operating model



to conceptual objectives.

We were also provided with Figure 2 that shows the design and implementation sequence for the strategy and framework (in Hydra). Figure 2 shows that ecosystem reference points are derived from both the simulated assessments, and the satellite derived primary production. It also shows modules within the multispecies fishery (operating) and assessment models.

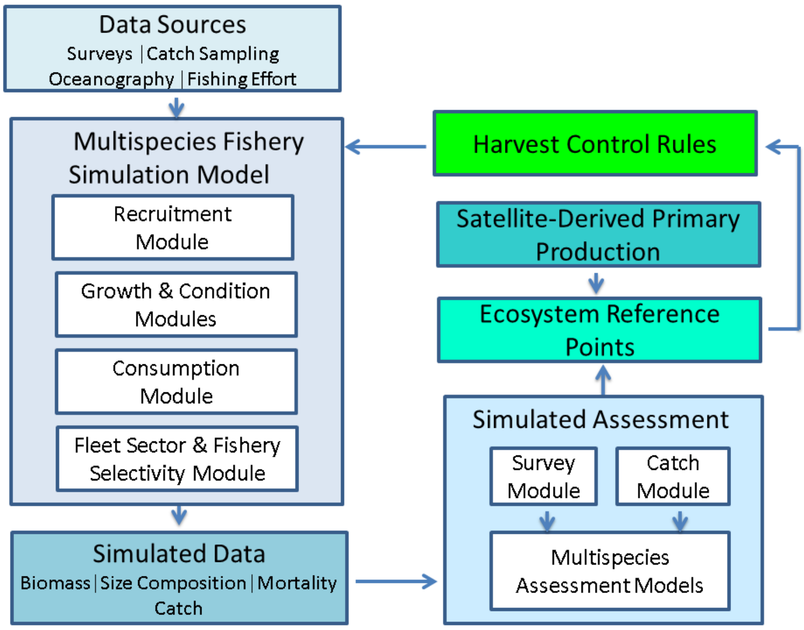


Figure 2: Modular design and implementation sequence in *Hydra.*

Reviewers were asked to evaluate selected operating models in relation to some "strawman objectives". Had different "strawman objectives" been chosen, these would have to be evaluated against different performance statistics, which may require different operating models. I would postulate that the NEFMC debate and decision about objectives may be substantially influenced by the kinds of operating models that are presented to simulate the multispecies fishery. For example, if only single species models were available to simulate the actual multispecies fishery of the region (in the real world, species interact and the fisheries are part of a coupled social-biological system, whether or not we have models that include interactions and other components of the system), then the chosen objectives would, out of necessity, be single species objectives. A variety of operating models will help to provide a broad range of options for debating and choosing objectives for EBFM and the process of choosing may require several iterations. Intercomparisons among models, that represent the same system in different ways, help to show up their strengths and weaknesses and may also reveal alternative or additional strategic and operational objectives. Once the objectives for EBFM are specified and agreed by the NEFMC, then operating models must obviously be capable of producing performance statistics to measure how well the chosen objectives are achieved.

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

In contrast to current management, which has evolved a patchwork of management areas for different species, Ecosystem Based Management (EBM) requires defined ecological regions (Ecological Production Units-EPU) for which integrated management plans can be developed. The question asked was whether one can identify a reasonably small number of spatial management units (EPU) using objective and consistent methods. The answer is broadly yes and the work presented provides a coherent spatial aggregation into EPUs, based on well established physical and biological characteristics that are suitable for the development of integrated management plans.

The variables used to determine EPU include bathymetry, surface sediment, temperature, salinity, stratification, chlorophyll and primary production (Table 1). Variables to represent higher trophic levels or fishing activity were not included, as they reflect human choices and activities that may not be related to the underlying ecological production systems. The data were standardised to annual means within spatial units of 10' latitude by 10' longitude, resulting in over 1000 spatial points, but omitting inshore (<27m) areas due to sampling limitations. A multivariate (Principal Component) analysis showed that the first component, accounting for 36.3% of the variance, was dominated by variablity in mean primary production, depth, fall salinity and mean chlorophyll. The second component (25.6% of variance) was dominated by temperature and salinity.

Table 1. The variables used as input for the PCA and clustering analysis showing their original data type, source, units, and time period.

Variables	**Sampling Method**	**Units**
Bathymetry	Soundings/Hydroacoustics	Meters
Surficial Sediments	Benthic Grab	Krumbein Scale
Sea Surface Temperature	Satellite Imagery (4km grid)	^{0}C annual average
Surface Temperature	Shipboard Hydrography (point)	^{0}C (Spring and Fall)
Bottom Temperature	Shipboard Hydrography (point)	^{0}C (Spring and Fall)
Surface Salinity	Shipboard Hydrography (point)	psu (Spring and Fall)
Bottom Salinity	Shipboard Hydrography (point)	psu (Spring and Fall)
Stratification	Shipboard Hydrography (point)	Sigma-t units (Spring and Fall)
Chlorophyll-a	Satellite Imagery (1.25km Grid)	mg C/m^3 (annual average)
Chlorophyll-a gradient	Satellite Imagery (1.25km Grid)	dimensionless
Primary Production	Satellite Imagery (1.25 km)	gC/m^2 /year (cumulative)
Primary Production gradient	Satellite Imagery (1.25 km)	dimensionless

Cluster analysis was used to group the >1000 spatial points initially into seven clusters. Nesting of nearshore and continental slope regions within adjacent shelf regions further reduced the number of clusters to four (Mid-Atlantic Bight, Georges Bank, Western-Central Gulf of Maine, and Scotian Shelf-Eastern Gulf of Maine).

The methods used to produce these EPUs are fairly standard, objective and consistent, and the outcome is reassuringly similar to previous mapping of EPUs for the NEFMC area (e.g.The Northeast Regional Ecosystem Plan (1988)). It is inevitable that mapping a wide range of biological and fisheries diversity (sizes, life histories, taxonomy, fishing methods, seasonal patterns) onto these EPU will result in some problems and misfits that require special treatment. However, the EPU are to be regarded as interconnected and having open boundaries that will be subject to periodic updates and reanalysis (5-10 year time scale) as climate, human use patterns, and other factors change.

Some specific, but by no means insoluble, problems are likely to arise within the NEFMC area where fishing activities frequently straddle the EPU boundaries (e.g., across the N boundary of Georges Bank), and where highly migratory species have ranges that extend well beyond those boundaries. My recommendation would be to agree on an outline strategy for tackling such problems as may arise before they become a major point of disagreement or conflict.

Future changes, including climate-induced changes, that are likely to affect the boundaries of EPUs were discussed. Since the boundaries are largely determined by elements that will not change over the next decades (e.g., bathymetry, coastal influence, tidal mixing, cross-shelf nutrient flux) the EPU boundaries should persist. Nevertheless, it is a fact that many of the most intractable fisheries disputes have arisen, because species distributions have, quite predictably, shifted across management boundaries (e.g., Dankel et al. 2015). Such disputes, arising from attempts to impose fixed boundaries on changeable biological entities (typically migratory species), could be regarded as self-inflicted problems. They can be avoided or mitigated by increasing the size of the spatial management units (EPUs) or by anticipating change and agreeing management procedures that will allow for time-varying EPUs or measures to deal with trans-boundary issues. While the proposed periodic update of EPU boundaries seems sensible it is also likely that time-varying EPUs would create their own set of problems for management. For example, it may be difficult to re-assign historic fisheries information (both commercial and research surveys) and to re-allocate historic catch shares to fit within new EPU boundaries.

Summary, conclusions and recommendations

The methods used produce a coherent spatial aggregation into EPUs that are consistent with earlier biogeographic regions and can be used as the spatial footprint for EBFM. There are likely to be some problems with species that migrate across boundaries and fishing activities that straddle them. I recommend agreeing on a strategy for dealing with migratory species in advance of any management problems that may arise from such migration.

Dankel, D. et al., 2015. *Allocation of Fishing Rights in the NEA*, Nordic Council of Ministers. Available at: http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-3942.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

This evaluation of ToR2 will consider first the methods used to estimate ecosystem productivity for the Georges Bank EPU, and second the suitability of these estimates for defining limits on ecosystem removals.

The estimates of ecosystem productivity for the Georges Bank EPU presented here build on a long and impressive history of research into primary and secondary productivity for this area. It is fair to say that many of the methods developed here represent the global state-of-the-art, and are emulated in other parts of the world. Fisheries production depends on the primary and secondary production (quantity and quality) that fish feed on. The aim is to determine the fisheries production *potential* of Georges Bank conditioned on the input of primary production and specified levels of trophic transfer efficiency. This aim is intuitively simple to grasp, but difficult to achieve for a number of reasons that can introduced with a terrestrial analogy.

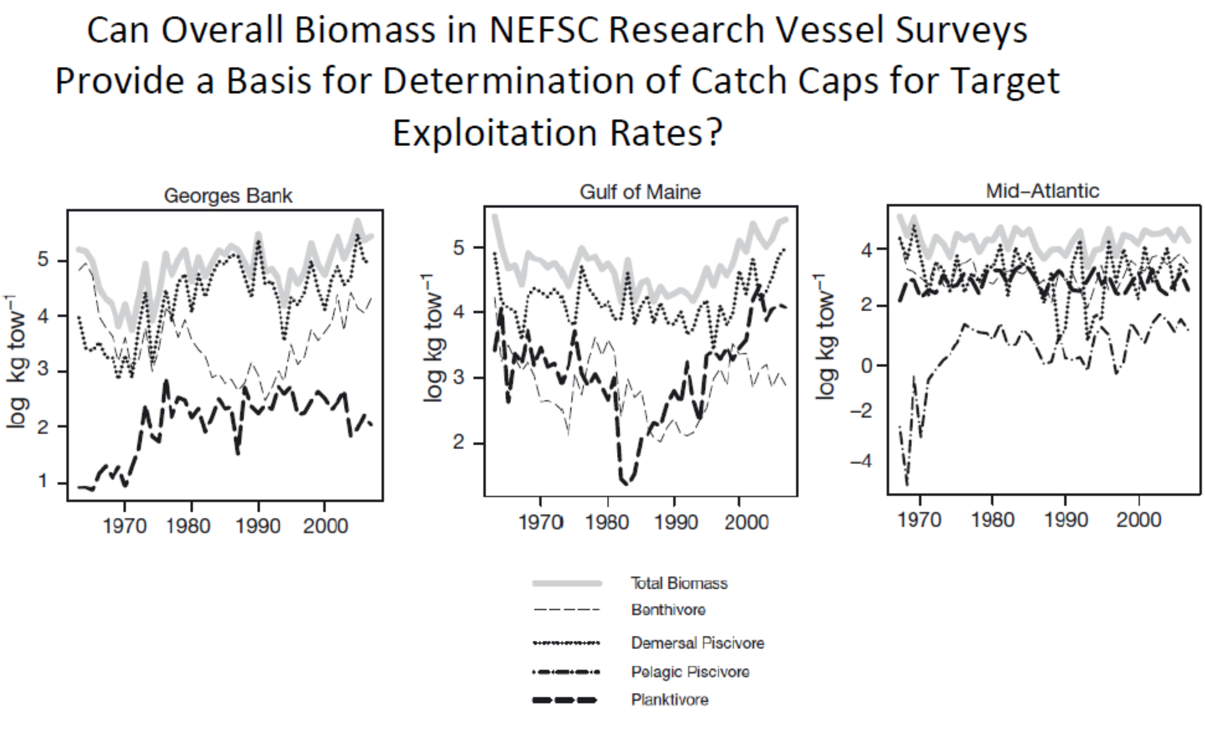
Until the advent of agriculture about 15K years ago, humans hunted and gathered their food from natural ecosystems. Planting and harvesting crops (agriculture) entailed (i) harvesting at the lowest trophic level (ii) harvesting a small number of species (iii) getting rid of predators and pests (iv) enclosing (owning) and cultivating. These actions can be regarded as forms of management that simplified and reduced the variability of the ecosystem in order to make it easier to control and predict, and also to increase the quantity of food produced. Of course none of these simplifying actions are proposed as part of EBFM here; rather, fisheries production potential of Georges Bank, and the consequent limits on removals, have to take account of explicit (e.g., mandated by law) and implicit constraints, which include (i) conservation of ecosystem structure, functioning and diversity (ii) maintaining existing species and size composition of fisheries catches (iii) maintaining viabilty of existing fisheries sectors.

All fisheries are a form of ecological engineering; we may regard the existing pattern of fishing and its concommitant ecological impacts as representing the “status quo” that we wish to persist, but this is a choice. Optimum yield, as defined for National Standard 1 (further discussed later under ToR 4) should take account of food production, recreational opportunities, intrinsic (existence) value, profitability, stability of biological and social systems, and protection of marine ecosystems. These affect the definition of limits on ecosystem removals, and also the species that are included in calculating those limits from the bottom-up trophic model. Such effects on limits are alluded to in the EBFM Summary Document when discussing “currently latent resources”: “Although the ecosystem risks of exploiting currently latent resources would need to be carefully evaluated, diversification of the exploitable resource base holds the potential to reduce pressure on the system overall if carefully implemented (Fogarty and Murawski 1997).” Similarly, a recently published study (Jacobsen et al. 2016) explored ecosystem-level efficiency of trade-offs between yield and conservation impact using a size-based 24 species model of the NE US Continental Shelf fisheries ecosystem and concluded that gains in both yields and conservation were possible with more efficient fisheries.

Jacobsen, N.S., Burgess, M. & Andersen, K.H., 2016. Efficiency of fisheries is increasing at the ecosystem level. *Fish and Fisheries*, 18(2), pp.199–211. Available at: https://doi.org/10.1111/faf.12171.

Moving on from the general issue of what is meant by “ecosystem limits on production” to the specific question of whether the methods of estimating ecosystem productivity presented here are suitable for defining limits on ecosystem removals as part of a management procedure, this is a matter of judgement and I would give a qualified yes. These productivity estimates are a very good starting point for EBFM and they can be used to establish guide values on the likely limits to fisheries production. An impressive effort has gone into quantifying the uncertainties associated with the estimates of ecosystem and species guild (functional group) production, but it is clear from the medians and quartile ranges in Tables 2.1 and 2.2 of the EBFM Summary Document that while the results may have sufficient precision for strategic guidance, they are probably insufficiently accurate and precise for shorter term use. Similarly, I would question whether the claimed secular trends in species guild production, arising from apparent increases in primary production are sufficiently well established to form part of the narrative on future harvest limits, at least until the processes (e.g., role of horizontal, cross shelf nutrient fluxes, role of transport processes along the Scotian Shelf and onto Georges Bank, long term effects of NAO, etc.) are well established, credible and predictable.

As a qualification on the previous paragraph, I note that the secular trends in primary production and consequent bottom-up trophic model estimated trends in fish guild production are not the only evidence that we have. NEFSC research vessel(RV) surveys show comparable trends for fish guilds; the question of whether these could provide a basis for defining limits on fisheries production will be addressed under ToR5.



Very extensive historic sampling of stomach contents from trawl surveys is used to estimate feeding preference and trophic levels, and to define membership of feeding guilds of fish. Detailed feeding data is a key component of the models used here. The feeding interconnections (as predators and prey) between species are complex, but in spite of their detail and complexity, the feeding data used here also constrain the domain of the model to species and sizes that are captured by the stomach surveys. Early life history stages (often referred to as pre-recruit stages), which may play an important role in biological interactions between species, are omitted. Many species of fish undergo ontogenetic shifts in their trophic status, so for example first feeding cod larvae are planktivores, with a requirement for food that will fit their jaw gape. Juvenile cod settle to the seabed and become benthivores switching gradually to an increasing proportion of fish in their diet. Furthermore in the current models, when species A eats species B this causes mortality on species B, but does not affect the growth or survival of species A. The consequences of these limitations for both the models of ecosystem production and the operating models for the multispecies system are hard to evaluate, but intercomparison with models that represent the dynamics in different ways, such as the one refererred to above that uses a simpler, size-based representation of trophic interactions, will help to show up relative strengths and weaknesses. Models with a small number of empirical and mechanistic (physiological) parameters lack detail, but will run faster than models containing a large number of mainly empirical parameters, making it easier to explore the limits and behaviour of the coupled social-biological fisheries ecosystem.

Summary, conclusions, and recommendations

Bottom-up estimates of ecosystem productivity for the region are based on state-of-the-art methods and excellent monitoring, but estimates of limits for ecosystem removals at higher trophic levels (including piscivorous fish) are inevitably subject to considerable uncertainty. Regular RV fishing surveys provide estimates of fish biomasses, and I recommend that these should be used to enhance confidence in the bottom-up estimates of limits. I also recommend evaluating other types of model (e.g. size and trait based ecosystem models) to provide alternative views on the limits for ecosystem removals.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

The approach and rationale for specifying Fishery Functional Groups (FFG) stem from the technical and biological interactions in mixed fisheries and the purpose of the FFG is to help address the problems that these interactions give rise to. They are also intended as a possible means to reduce the cost and complexity of managing mixed fisheries. The technical interactions mean that particular fishing gears and fleet sectors exert a fairly set pattern of exploitation across a range of species. The biological interactions mean that species interact with each other due to predation and competition.

FFG are defined as comprising species that are caught together by specified fleet sectors and that play similar roles in the ecosystem with respect to energy transfer. FFG include both fleet (sectors, metiers) and species variables, with the latter being nested in the former i.e., particular fleet sectors that catch particular groups of species.

One can postulate that there is a pattern or set of values of fishing mortality that would result in some desirable optimal yield from the ecosystem. However, that pattern may not be attainable unless there is a combination of effort by existing FFG that achieves it. In using FFG as management units, it may nevertheless be possible to get closer to the desired optimum than with alternative management units, and they may also offer a simpler form of management. Such optimisation would of course also be constrained by conservation limits (e.g., minimum biomass limits on vulnerable species).

The idea of using FFG as management units entails aggregation of species with similar trophic and life history characteristics (e.g., benthos, planktivores, benthivores, piscivores) which brings with it the possibility of managing their aggregate yield instead of (or as well as) setting targets or limits for individual species. Benefits in terms of simplification and stability could result from management of aggregate yields of FFG, with lower (assessment and regulatory) costs and improved stability of aggregate catches due to trade-offs between species that average out the natural variability in individual species productivity (e.g., due to recruitment) from year to year.

Some of the information needed to evaluate ToR3 will be covered by ToR 4, which applies performance metrics to evaluate the performance of FFG aggregate management in combination with fixed and ramped biomass limit rules. It would additionally be interesting to see a comparison using the same performance metrics with existing single species management. However, such a comparison may be limited by the current single species coverage.

Summary, conclusions and recommendations

The approach and rationale used here to specify FFG are well thought through and appropriate for the purpose they are to serve. Further testing both in simulations and in practice will be needed to determine how effective they are and in what ways they may require adjustment. I recommend development of performance metrics specifically to measure the effectiveness of FFG in relation to technical and biological interactions, since this is a key issue in dealing with problems of multispecies fisheries in the area.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

The Georges Bank EBFM summary document does not mention "strawman objectives" other than in citing ToR4, however they were explained in the presentation and subsequent discussion as being strategic and operational objectives that will be used in preliminary testing of the fishery ecosystem plan (FEP) and that are linked to performance metrics. "Our objectives are to maintain overall system resilience and to optimize yield and revenues subject to conservation constraints." System resilience and conservation constraints are to be maintained by setting a floor for biomass at the FFG or individual species level, with management action triggered at or before this threshold is reached. Yield is optimised by setting limits on the catch in order to maintain biomass above the level needed to maintain that level of production. The "strawmen" have not been formally adopted by the Council, nor have stakeholders yet been involved in the development of objectives at this stage.

In reviewing the proposed implementation of EBFM, and specifically in addressing ToR4, one can distinguish between (i) commenting on the applicability and utility of the particular strawman objectives identified above from the material provided and the subsequent discussion, and (ii) commenting on the role of these strawman objectives as a contribution to the development and adoption of objectives by the Council and also in informing the debate with stakeholders.

This matters, because the development of particular operating models is guided by how well they perform (using agreed metrics) in relation to agreed objectives, but the development and choice of objectives also depends on the kinds of operating models which are used to represent the real world. For example, if the only operating models available are single species models, then the choice of objectives will reflect that. The "**Preamble on interdependence of objectives and tools"** above discusses the mutual and iterative relationship between tools (including models) and objectives.

The presentation explained that "optimal yield" was defined in National Standard 1 as applying to a "fishery", and that optimal yield should take account of food production, recreational opportunities, intrinsic (existence) value, profitability, stability of biological and social systems, and protection of marine ecosystems. A "fishery" was defined as "one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographic, scientific, technical, recreational, and economic characteristics". NS1 thus permits an aggregate approach to estimating the maximum sustainable yield of a fishery and also the use of EBFM.

The "strawman objectives" took account of the state of the ecosystem, functional groups and individual species and were based on the following Strategic Objectives:

1. Maintain/restore sustainable production levels (ecosystem, functional group emphasis)
2. Maintain/restore biomass levels (functional group/species scale emphasis)
3. Maintain/restore functional trophic structure

and the following Operational Objectives:

1. Ecosystem and community/aggregate fishing mortality and/or total catch is below established dynamic threshold
2. Fishing-related mortality for threatened/endangered/protected species is minimized
3. Managed and protected species biomass is above established minimum threshold
4. Maintain ecosystem structure within historical variation, recognizing inherent dynamic properties of the system; Ecosystem structure includes size structure, trophic structure, and functional group structure
5. Maintain habitat productivity and diversity
6. Habitat structure and function are maintained for exploited species
7. Minimize the risk of permanent (>20 years) impacts; e.g. Corals and sponges; Other vulnerable biogenic habitats; Coastal habitats vulnerable to Aquatic Invasive Species (AIS); Vulnerable physical habitats (e.g. relict glacial gravel banks)

These lists of potential management objectives will ultimately inform the debate and selection of objectives by stakeholders in collaboration with the NEFMC.

The performance metrics presented were:

1. Functional Group Status (Proportion overfished/depleted)
2. Species Status (Proportion overfished/depleted)
3. Landings
4. Biomass at Species and Functional Group Levels
5. Stability of Landings
6. Large Fish Index (Population)
7. Large Fish Index (Landings)
8. Revenue

Summary, conclusions and recommendations

If optimal yield (as defined for National Standard 1) is to take account of food production, recreational opportunities, intrinsic (existence) value, profitability, stability of biological and social systems, and protection of marine ecosystems, then the strategic and operational objectives listed above fall short, since they deal mainly with maintaining and restoring biological structure and productivity. It is not very clear how performance metrics 5 and 8 emerge from the presented strategic and operational objectives, but they undoubtedly address attributes of NS1 optimal yield ("profitability", "stability of biological and social systems").

It is not obvious how operational objective 7 relates to the strategic objectives, nor does it appear to have an associated performance metric, but it does clearly relate to the attributes "intrinsic value" and "protection of marine ecosystems".

The "strawman objectives" will likely contribute to framing the debate on objectives among stakeholders and the Council; therefore, it is important that (within the frame already established by legislation and the status quo) they should be reasonably neutral and comprehensive so that other options are not precluded. It is inevitable that there will be conflicts and trade-offs between different attributes of "optimal yield" (e.g., between conservation and profitability attributes) and the scope of the performance metrics should be broad enough to allow such trade-offs to be quantified. I recommend additional "strawman" objectives dealing with economic, social and conservation attributes in order to broaden the framing of the debate and subsequent choice of objectives.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

The rationale for proposing a management control rule (MCR) or rules for ecosystem-based fishery management is well presented and compelling. Proposed management reference points, which are part of the MCR, are specified in ToR 5 and include catch ceilings for each EPU and FFG and minimum permitted biomass levels (floors) for each individual species. The catch ceilings are intended to limit the rate of removal to a level below overfishing and the biomass floors are intended to maintain all species within safe conservation limits.

As with any ceiling and floor reference points, there are questions about how they are estimated, whether they change over time, and if so, how frequently they should be updated, whether they may inadvertently act as targets rather than limits (especially the catch ceiling), whether all species are included (e.g., rare and vulnerable species), whether they are affected by environmental changes (e.g., direct and indirect climate impacts), how and when action to avoid breaching them is triggered, etc. Some of these will be considered further.

Methods for estimating ecosystem productivity and limits on removals for EPU and fish guilds were evaluated under ToR 2. While the accuracy and precision of the limits estimated from trophic models raise questions about their utility as part of a management control rule, they could be used to complement data provided by regular fishing survey to make them fit for purpose. The phrase "conditioned on environmental conditions" in ToR5 may cover a range of possible conditions, but one which has been mentioned is the apparent increasing trend in primary production and in survey indices of some fish guilds on Georges Bank. A well established and credible explanation of the causes of the apparent increase in primary production would strengthen the case for allowing these trends to influence catch caps.

The utility of biomass floors as part of the MCR depends on how such floors are defined and estimated, and on how effective the management control rule is in preventing them from being breached. This is a very complex issue that cannot be addressed briefly, so only a couple of suggestions will be presented. If the MCR is intended to simplify management and operate at an aggregate level (EPU and FFG), then, other things being equal, it could be regarded as retrograde to introduce biomass limits on each individual species. An alternative would be to identify a (regularly updated) subset of particularly vulnerable species to act as the "canary in the coalmine" for biomass limits. Focusing the conservation effort on particularly vulnerable species or groups may also pave the way for special protection of those species, based on seasonal and/or area controls that take into account their life histories, seasonal distribution and fisheries that exploit them accidentally or deliberately (e.g. Dedman 2016).

Summary, conclusions and recommendations

The case for these "ceiling and floor limits" to prevent overfishing and to avoid any stock being overfished is well made. However, I express a number of concerns about how the limits will be estimated, whether and how often they will change and how they would be applied.

Dedman, S. et al., 2016. Towards a flexible Decision Support Tool for MSY-based Marine Protected Area design for skates and rays. *ICES Journal of Marine Science: Journal du Conseil*, 74(2), pp.576–587. Available at: http://icesjms.oxfordjournals.org/content/early/2016/08/26/icesjms.fsw147.abstract.

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

The harvest control rules (HCR) were evaluated by applying three "threshold" and three "ramp-down" exploitation rate scenarios to the multispecies fisheries simulation (operating) model. For each scenario, system based exploitation rates ranging from 0.05 to 0.4 were applied. The evaluation used performance metrics for revenue, functional group status, species status, landings, biomass, stability of landings, the proportion of large fish in the population, and the proportion of large fish in the landings. Results were presented for years 21-30 and 41-50 of the simulations.

Threshold scenarios performed significantly worse for all metrics than ramp-down scenarios, except at low exploitation rates. At high exploitation rates, the performance of the threshold scenarios was poor, even with enhanced protection for the most vulnerable species. The ramp-down scenarios in which exploitation is progressively reduced once defined trigger levels of biomass are reached and in which biomass floors were implemented for functional groups, rather than for individual species, result in greater resilience to higher exploitation rates and higher revenues, landings, and stability of landings. Highest revenues occurred at an exploitation rate of 0.25 under this scenario. The ramp-down strategy with biomass floors for individual species performs better for metrics related to conservation status than when protections are implemented only at the functional group level as nominal exploitation rates increased.

Summary, conclusions and recommendations

Applying the various scenarios of the HCR to the operating model produces simulations that are intuitively sensible. Implementing HCR at aggregate (EPU and FFG) level seems a viable option and the results provide guidance on adopting HCR in the real world, for example, showing the benefits of ramped rather than threshold limitation of exploitation rates. It is likely that other options for HCR will be put forward during discussions with stakeholders, and the operating model should be able to deal with these in a flexible way. One option which would clearly be useful to evaluate for comparison would be to emulate the existing management strategy.

It is recommended that ramped reduction in exploitation that is triggered in steps, should be avoided. A smooth rather than stepped response should help to avoid arguments about whether or not the estimated biomass falls above or below the level for triggering the next stepped reduction in exploitation.

ToR 7: Review the structure and application of operating models for Georges Bank.
ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.
ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

The two operating models under review were Hydra (a multispecies-multifleet length-structured simulation model) and Kraken (a multispecies production model).

The example of Hydra here included ten species (Atlantic cod, haddock, silver hake, winter flounder, yellowtail flounder, monkfish, spiny dogfish, winter skate, Atlantic herring, and Atlantic mackerel) and three fishing fleets (demersal trawl, fixed gear (longline and gillnet), and pelagic trawl).

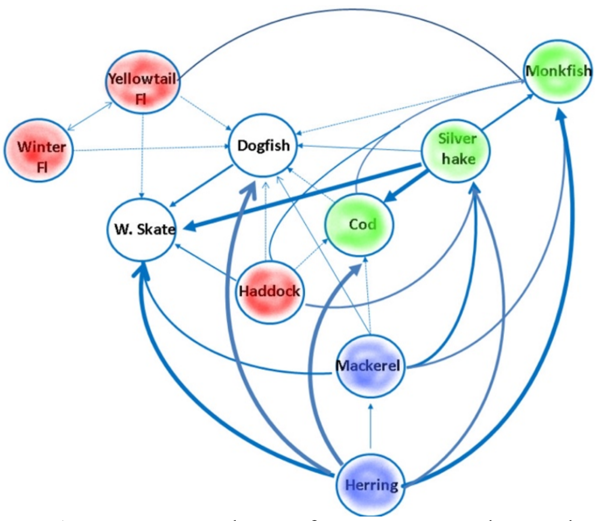


Figure - Arrows trace pathways from prey to predators; the width of the lines indicates the relative average importance of a prey species to a predator based on an extensive compilation of food habits data obtained during standardized NEFSC research-vessel surveys. red – benthivores, white – elasmobranchs, green – piscivores, blue – planktivores.

I commented under ToR 2 on the constraints that arise from the using only trophic data from the NEFSC standardized RV surveys to represent feeding relationships, and this can be illustrated by the Figure above. For example, cod is predated on by herring and mackerel in early life stages, and is a planktivore and a benthivore during early life before shifting mainly to piscivory, but these ontogenetic trophic changes are not included in Hydra. The consequences of these early life trophic interactions are in effect included in the stock-recruitment part of the Hydra model, but it would be worthwhile using other models to explore possible consequences of dealing with such early life interactions more explicitly than via the stock-recruit relationships.

The Kraken model framework was implemented here as a multispecies surplus production, used to simulate the annual biomasses of ten Georges Bank species using logistic equations. It shows promise in exploring some of the economic attributes of optimum yield by coupling with portfolio analysis to trade-off yield maximisation against risk, which shows how important risk management is for sustainable fisheries. It was also used to evaluate management procedure using ceilings on system removals, and showed that most of the variability in performance metrics is explained by catch ceilings, with lower catches traded off against reduced frequency of collapse and increased diversity. This and other relatively simple multispecies simulation models can be used to explore dynamics in relation to economic and social attributes, but they also require further evaluation to test their performance against historic data and trends.

In relation to assessment methods, the alternatives presented included outputs from simulated surveys, multispecies production models and multispecies delay-difference model. The models require biomass and catch data as inputs.

Summary, conclusions and recommendations

There are inevitable trade-offs in modelling between on the one hand detail and seeking to represent the real word closely, and on the other hand going for the simplest representation that captures the dynamics that matter for the question at hand. The Hydra and Kraken simulations could be regarded as an example of each. It would be worthwhile also to use other models that include the full size spectrum of fish life histories and therefore take account of early life interactions.

The simulated stock assessments should be compared with current single species stock assessments as a step towards carrying out full management strategy evaluation, bearing in mind that the first step towards EBFM is to show that it is an improvement on current management.

Critique of the NMFS review process

The review process was detailed thorough, and open, with ample opportunities for discussion and input from scientists, Council members and the panel. The presentations were uniformly excellent, and our questions were dealt with fully and clearly. In retrospect, there were questions that at the time seemed naive, but should have been asked, such as “can we have a short clear statement of what the “strawman management objectives” referred to in ToR 4 are

The provision of documents and web-based information, including access to the meeting wi-fi and access to the timetable and presentation material, could have been better. Given the long delay between the initial and final review dates, this material could usefully have been made available sooner. The delay that resulted from the US Government shutdown in January wasted a lot of time for a lot of people.

APPENDIX A

Documents for Review

The main document provided for reviewed by the Panel was an overview of the EBFM management procedure:

NEFSC Fishery Ecosystem Dynamics Assessment Branch. 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. April 20-May 2, 2018, Woods Hole, MA. https://www.nefsc.noaa.gov/program_review/docs/Georges%20Bank%20EBFM%20Summary%20Document.pdf.

In addition, the following background materials were reviewed by the Panel:

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for Prototype Georges Bank, Fishery Ecosystem Plan. Catch Advice Framework, a Worked Example #2. New England Fishery Management Council. September 26-28, 2017. http://s3.amazonaws.com/nefmc.org/2_A-Framework-for-Proividing-Catch-Advice-for-a-Prototype-Georges-Bank-FEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for a Fishery Ecosystem Plan (FEP). New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. DRAFT: Example application of operation models for Georges Bank ecosystem production unit (EPU) strategy evaluation. New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-3.-Example-application-of-operating-models-for-Georges-Bank-ecosystem.pdf.

Fogarty, M. J., Overholtz, W. J., Link, J. S. 2012. Aggregate surplus production models for demersal fisher resources of the Gulf of Maine. Marine Ecology Progress Series, 459:247-258. https://www.nefsc.noaa.gov/program_review/docs/b4-fogarty%20et%20al%20MEPS.pdf.

Gaichas, S., Gamble, R., Fogarty, M., Benoît, H., Essington, T., Fu, C., Koen-Alonso, M., Link., J. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Marine Ecology Progress Series, 459:275-292. https://www.nefsc.noaa.gov/program_review/docs/b5-Gaichas%20et%20al%20MEPS.pdf.

Gamble, R. J., Link, J. S. 2012. Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community. Marine Ecology Progress Series, 459:259-274. https://www.nefsc.noaa.gov/program_review/docs/b-6Gamble%20and%20Link%20MEPS.pdf.

Hennemuth, R. C., Rothschild, B. J., Anderson, L. G., Kund, Jr., W. A. 1980. Overview Document of the Northeast Fisher Management Task Force, Phase 1. NOAA Technical Memorandum NMFS-F/NEC-1. October 1980. https://www.nefsc.noaa.gov/program_review/docs/b3-tm-1-hennemuith.pdf.

Link, J. S., Gamble, R. J., Fogarty, M. J. 2011. An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management. Northeast Fisheries Science Center Reference Document 11-23. October 2011. https://www.nefsc.noaa.gov/program_review/docs/b2-crd-1123.pdf.

Lucey, S. M., Cook, A. M., Boldt, J. L., Link, J. S., Essington, T. E., Miller, T. J. 2012. Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern

hemisphere marine ecosystems. Marine Ecology Progress Series, 469:219-229. https://www.nefsc.noaa.gov/program_review/docs/b-7Lucey%20et%20al%20MEPS.pdf.
NEFMC Scientific and Statistical Committee. 2010. White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council. October 2010. https://www.nefsc.noaa.gov/program_review/docs/b1NEFMC%20EBFM%20White%20Paper_report_15%20oct%202010.pdf.

Presentations for Review
Presentations covered the following topics were reviewed by the Panel during the in-person meeting:

1. Objectives for the Review (Mike Simpkins, NEFSC)
2. Logistics (Rob Gamble, NEFSC)
3. NEFMC Ecosystem-Based Fisheries Management Plan Development Team (Andrew Applegate, NEFMC)
4. Background and Overview of Proposed Management Procedure (Mike Fogarty, NEFSC)
5. Defining Ecological Production Units (Robert Gamble, NEFSC)
6. Ecosystem Production Potential (Michael Fogarty, NEFSC and Kimberly Hyde, NEFSC)
7. Defining Fisheries Functional Groups (Sean Lucey, NEFSC and Mike Fogarty, NEFSC)
8. Strawman Management Objectives and Performance Metrics (Richard Bell, The Nature Conservancy)
9. Ecosystem-Based Reference Points (Mike Fogarty, NEFSC)
10. Harvest Control Rules (Mike Fogarty, NEFSC)
11. Structure and Application of Operating Models -- Part 2 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)
12. Structure and Application of Operating Models --Part 2 Kraken (Robert Gamble, NEFSC and Geret DePiper, NEFSC)
13. Structure and Application of Assessment Models (Charles Perretti, NEFSC and Mike Fogarty, NEFSC)
14. Simulation Tests and Performance Management Procedure -- Part 1 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)
15. Simulation Tests and Performance Management Procedure -- Part 2 Kraken (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

APPENDIX B

Final Terms of Reference
Ecosystem Based Fishery Management Strategy Review
April 30-May 3, 2018
NOAA Fisheries/Clark Conference Room
Woods Hole MA

Objective 1
Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the New England Fishery Management Council. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC strawman management objectives as well as evaluate a worked example intended to simulate the performance of the EBFM procedure. (The strawman objectives were used to develop the EBFM strategy and framework; final objectives will be developed and approved by the NEFMC at a later date.)

The reviewers will be asked to provide recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a SAW/SARC assessment review).

The review will encompass the EBFM procedure, the potential operating models used to test the procedure, and a worked example of the relative performance of the EBFM procedure for providing quota advice as they pertain to fisheries management of Georges Bank fisheries.

If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group OFLs, potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Objective 2
Review the proposed strategy for implementing EBFM on Georges Bank

Terms of Reference

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

APPENDIX C

Agenda, Documentation, and Presentations for 2018 Ecosystem Based Fishery Management (EBFM) Strategy Review

Date	*Time*	*Topic and Related Documents*	*Presenter/Lead*	*Theme Area*
Monday April 30	9:00 AM	**Welcome and Objectives for the Review** Background Documents **Ecosystem-Based Fishery Management Strategy** **Georges Bank Prototype Study Summary Document** **White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council (2010)** **An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management** **Overview of the Northeast Fishery Management Task Force Phase 1 (1980)** **Aggregate surplus production models for demersal fishery resources of the Gulf of Maine** **Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation** **Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community** **Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems**	Jon Hare *NEFSC Science and Research Director* Mike Simpkins *Resource Evaluation and Assessment Division Chief*	
	9:15 AM	**Logistics**	Robert Gamble, NEFSC	
	9:30 AM	**NEFMC Ecosystem-Based Fisheries Management Plan Development Team** Background Documents **A Framework for Providing Catch Advice for a Prototype Georges Bank Fishery Ecosystem Plan** **A Framework for Providing Catch Advice for a Fishery Ecosystem Plan** **DRAFT: Example application of operating models for Georges Bank ecosystem production unit (EPU) strategy evaluation**	Andrew Applegate, NEFMC	
	10:00 AM	**Background and Overview of Proposed Management Procedure**	Michael Fogarty, NEFSC	
	10:30 Break			
	11:00 AM	**Defining Ecological Production Units**	Robert Gamble, NEFSC	TOR 1
	11:30 AM	**Ecosystem Production Potential**	Michael Fogarty, NEFSC Kimberly Hyde, NEFSC	TOR 2
	12:00 Lunch			
	1:30 PM	**Defining Fishery Functional Groups**	Sean Lucey, NEFSC Mike Fogarty, NEFSC	TOR 3

	2:00 PM	**Strawman Management Objectives and Performance Metrics**	Richard Bell The Nature Conservancy	TOR 4
	2:30 PM	**Ecosystem-Based Reference Points**	Michael Fogarty, NEFSC	TOR 5
	3:00 Break			
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Tuesday May 1	9:00 AM	**Harvest Control Rules**	Mike Fogarty, NEFSC	TOR 6
	9:30 AM	**Structure and Application of Operating Models -- Part 1 Hydra**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 7
	10:30 Break			
	11:00 AM	**Structure and Application of Operating Models -- Part 2 Kraken**	Robert Gamble, NEFSC Geret DePiper, NEFSC	TOR 7
	12:00 Lunch			
	1:30 PM	**Structure and Application of Assessment Models**	Mike Fogarty, NEFSC	TOR 8
	2:00 PM	**Simulation Tests and Performance Management Procedure -- Part 1 Hydra**	Andy Beet, NEFSC Michael Fogarty, NEFSC	TOR 9
	3:00 PM Break			
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Wednesday May 2	9:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 1 Hydra, continued**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 9
	10:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken**	Amanda Hart, UMASS Dartmouth Geret Depiper, NEFSC Robert Gamble, NEFSC	TOR 9
	10:30 Break			
	11:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken,continued**	Geret Depiper, NEFSC Robert Gamble, NEFSC Amanda Hart, UMASS Dartmouth	TOR 9
	12:00 Lunch			
	1:30 PM	**Open Question Period**		
	3:00 PM Break			
	3:30 PM	**Public Comment Period**		
	4:30 PM	**Review Panel Discussion (private)**		

Thursday May 3	9:00 AM	**Review Panel Report Writing (private)**		

APPENDIX C

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APPENDIX D

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Ecosystem Based Fishery Management Strategy Review

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

Ecosystem Based Fishery Management (EBFM) Strategy Review

Objective: Review a proposed implementation of EBFM for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the NEFMC. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC management objectives, as well as evaluate an "operating model" intended to simulate the performance of the EBFM procedure. The "operating model" in this case is a multi-model suite that can include empirical approaches as well as simulation models. The reviewers will be asked to provide recommendations to improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) review process).

The review will encompass the EBFM procedure, the suite of operating models, and a worked example of quota advice as they pertain to fisheries management in the Northeast region.
If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group Overfishing Limits (OFLs), potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Reviewer Requirements

NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the SOW, OMB Guidelines, and the TORs below. The reviewers should have working knowledge and recent experience in ecosystem-based fishery management particularly in areas of Management Strategy Evaluation/Management Procedures, Fishery Ecosystem Plans, Integrated Ecosystem Assessments, ecosystem models, multi-species models, population dynamics, harvest strategies, and fisheries management regulations as they apply to EBFM. We prefer having at least one international reviewer and at least one reviewer from the U.S. The third reviewer can be an international or U.S reviewer.

Tasks for Reviewers

1. Review background materials and reports prior to the review meeting related to the Terms of Reference.
2. Attend and participate in the panel review meeting
    a. The meeting will consist of presentations by NOAA and other scientists, and other experts to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
3. After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
4. Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
5. Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at Northeast Fisheries Science Center Woods Hole, MA

Period of Performance
The period of performance shall be from the time of award through March 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
January 2017	Panel review meeting
Approximately 3 weeks later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:

Robert Gamble
166 Water Street
Woods Hole, MA 02543
robert.gamble@noaa.gov

Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review
Appendix 2: A copy of this Statement of Work
Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Ecosystem Based Fishery Management Strategy Review at the Northeast Fisheries Science Center, Woods Hole MA

External Independent Peer Review

by

Villy Christensen

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Prepared for the Center for Independent Experts

June 2018

Executive Summary

The Ecosystem Based Fishery Management Strategy review was organized by the Northeast Fisheries Science Center (NEFSC) and chaired by Dr Lisa Kerr, Gulf of Maine Research Institute and NEFMC Scientific and Statistical Committee. The review team included Dr Keith Brander, DTU Aqua, Copenhagen; Dr Daniel Howell, IMR, Bergen; and myself, Dr Villy Christensen from UBC, Vancouver, BC. Jointly, we conducted a review of a proposed methodology for incorporation of EBFM at the New England Fisheries Management Council (NEFMC). The review took place over four days where scientists from NEFSC and other institutions, led by Dr Mike Fogarty made numerous presentations covering all ToRs, and where there were 20-25 people in attendance each day.

In summary, my findings about the specific ToRs for the review are:

- ToR 1: The approach for defining Ecological Production Units is sensible, well-defined, and ready for use;
- ToR 2: The methods for evaluating ecosystem production potential may well be used to provide indicators for how the fisheries production may change, at least in a directional sense. The evaluations are, however, too uncertain when it comes to use for setting precise overall system caps;
- ToR 3: The approach for defining Fishery Functional Groups (FFGs) is well defined and conducted, and it will be interesting to see further work on the topic, including mapping onto the New England Groundfish Clusters and other actual fisheries management units;
- ToR 4: The “strawman” management objectives were broadly defined (as they should be) but fall short in what they cover. The operational objectives were general and rudimentary, and it was not clear how these would be translated into measurable objectives and metrics;
- ToR 5: The ecological reference points include catch caps overall and by FFGs, and limit reference biomass by FFG and by species. My recommendation is to use the caps as reference levels, and while the biomass floors were reasonable to use in the Hydra demonstration at the review, it is unclear how and if they can be convincingly implemented in real world applications;
- ToR 6: The Harvest Control Rules were well-defined for the specific use, i.e., to evaluate a range of possibilities. I do, however, not consider that they as defined are suited for actual implementation in real world Management Strategy Evaluations (MSEs);
- ToR 7: Two “operating” models were presented. The Hydra model is an interesting model, but needs refinement before it can be used in a credible manner to evaluate realistic HCRs. The limited implementation of the Kraken model complex makes evaluation of its potential for use as part of the EBFM rather impossible to

evaluate at present. Overall, I recommend in accordance with best practices for MSE that the group evaluates the feasibility of using MSE tools that have been developed for broad application;

- ToR 8: I consider the choice of assessment models pertinent; for the purpose of evaluating HCRs there is no need to implement the actual assessment models that will be used for eventual quota settings;
- ToR 9: The simulation tests as demonstrated at the review were cursory and incomplete, and even if some preliminary results seem plausible, others do not. I recommend to follow best practices for MSE and apply a portfolio approach to the simulations.

Overall, I note that the group at NEFSC-EAP is very capable, but are faced with a major task in developing procedures for actual implementation of EBFM. There are no clear models for how this should be done from other NOAA Centers, and it is not a simple task when it has to be done to the level and scrutiny required by Fisheries Management Councils. Still, it can and should be done.

The group involved in the EBFM development currently involves seven researchers, but with an effort level that corresponds to less than two person-years annually. I consider this vastly insufficient for full and credible development. The implementation of the pilot study has not yet attained a level where it credibly can be used to evaluate how EBFM should be implemented or what the consequences of the implementation might be. The work that has been done, however, represents a significant step on the way towards EBFM, and for this it should be complimented.

For the review, the Council explicitly asks for guidance on whether the proposed tools and approach would provide them with the tools they need for implementation of EBFM. The overall conclusion is that the required tools are not yet in place, even though considerable progress was demonstrated for the review. Following best practices for EBFM, including application of multiple model approaches and with emphasis on broadly developing model approaches is recommended as the fastest option.

Looking beyond the immediate requirement of NEFMC for implementation of EBFM, I note that NEFSC is tasked with the implementation of the National Ocean Policy (even if there's uncertainty about the future of the act) and that this calls for development of the scientific architecture in support of EBM. This includes development of methods to evaluate multi-sectoral policy questions, including ones related to land-coast interactions, spatial planning, energy development and numerous other issues, including EBFM and climate change adaptation. I do not have the impression that the Center has moved very far on this since 2011, and therefore strongly recommend, as I did back then, that the

NEFSC evaluates the resource allocation that implementation of EBFM and indeed of the overall EBM modeling strategy will call for.

Table of Contents

Background

The New England Fisheries Management Council (NEFMC, the Council) decided in 2008 to develop and implement an Ecosystem-Based Fishery Management (EBFM) plan and tasked its Scientific and Statistical Committee (SSC) to provide a strategic plan for this (NEFMC SSC, 2010). Implementation aspects of this were primarily the responsibility of the Northeast Fisheries Science Center (NEFSC, or the Center), and among others included development of a suite of multispecies and ecosystem modeling tools. These tools were reviewed as part of a CIE review in 2011[1], in which the present reviewer participated as a panel member.

The development was, however, delayed at the Council's request, due to pressing management issues, but it has been initiated again, and the intention is now (according to the Council website) to explore EBFM, "a new approach that involves all species and fisheries in a specific area, recognizes the energetic limits of the system, takes into account the trophic relationships among species, allows for greater adaptability to variability and change, and addresses multifaceted goals and objectives. As a first step, the Council is developing an example Fishery Ecosystem Plan for Georges Bank that will be used to solicit and focus public input. The example could lead to the development of a new Fishery Ecosystem Plan or contribute to a set of ecosystem policies and initiatives that would apply across multiple fishery management plans."

The development of EBFM in New England is in line with international and national strategies. NOAA indeed strives to adopt an ecosystem-based approach throughout its programs and regions, including EBFM as a central part of future management. As part of the move, the NOAA Science Centers are encouraged to develop Fisheries Ecosystem Plans, and such have now been developed for four of the Centers, with several more in progress. Still, it is noteworthy that few Centers and Councils have reached the state of EBFM implementation that has led to CIE reviews of their strategy or implementation. Underlying model approaches have thus been reviewed for Alaska in 2005, for New England in 2011, and for the Pacific Islands and the Northwest Pacific in 2014. The present review is the first to deal with implementation of EBFM, so it seems that NEFMC indeed is breaking new ground – surprisingly, giving the long-standing strategy in NOAA for EBFM.

As part of the Council's exploration of options for introduction of EBFM, it requested NOAA's Office for Science and Technology for an initial EBFM strategy implementation review through the Center for Independent Experts (CIE). The ensuing review was focused on a proposed management procedure developed by NEFSC's Ecosystems Dynamics &

[1] 2011_04_14; https://www.st.nmfs.noaa.gov/science-quality-assurance/cie-peer-reviews/cie-review-2011

Assessment (EDA) branch in cooperation with other units, and was to include evaluation of the models and approach used to test the proposed EBFM procedure. It is the expectation that an EBFM approach will include wider representation of factors in the management than currently considered, notably with regards to ecosystem and human components.

The EBFM Strategy review was organized by the NEFSC, and chaired by Dr Lisa Kerr, Gulf of Maine Research Institute and NEFMC Scientific and Statistical Committee. The review team included Dr Keith Brander, Danish Technical University Aqua, Copenhagen, Denmark; Dr Daniel Howell, Institute for Marine Research, Bergen, Norway; and myself, Dr Villy Christensen from The University of British Columbia in Vancouver, BC.

Jointly, we conducted an external review of a proposed methodology for incorporation of EBFM in the New England area with a focus on Georges Bank. The review took place at NEFSC during four days in late April to early May 2018 where scientists from NEFSC, led by Dr Mike Fogarty made numerous presentations covering the nine specific ToRs, and where there were around 25 people in attendance each day (partly listed in Appendix 3 on page 46).

It is noted that the review was not meant to consider, evaluate or develop management recommendations, but rather consider a set of choices that may be explored in order to ensure that the Center has the tools required for developing EBFM in the future. In this context the development of Management Strategy Evaluation (MSE, Smith et al., 1999) alias Management Procedures (MP, Butterworth and Punt, 1999), or, as it was originally known and developed, closed loop analysis (Walters, 1986) forms a central part.

The perhaps key question asked of the review panel during the review was if we thought the research was on the right track.

Review Activities

The review started timely at 9 AM on April 20, 2018, with around 20 people in attendance (and with an additional handful trying to connect – eventually successfully – through a conference call line). The participants included the key representatives from the NEFSC-EAP and other parts of the Center as well as the review panel including Dr Lisa Kerr, Chair, and the CIE review team consisting of Drs. Keith Brander, Daniel Howell and Villy Christensen.

Dr Mike Simpkins (NEFSC Resource Evaluation and Assessment Division Chief) bid welcome (on behalf of Dr Jon Hare, NEFSC Science and Research Director), and emphasized the interest in moving forward with EBFM for the NEFSC area. For the present review, the Council had asked for a fully worked example to illustrate how EBFM might be implemented. The Council asked if the science underpinning the EBFM implementation is valid.

The Review Chair, Dr Lisa Kerr, continued and outlined that the review was a research track review with consideration of EBFM procedures, potential operating models, and that the role of the review was to provide recommendations based on the ToR. So, not to focus on output, but on approach, on evaluating the science, and the best practices for the approach for implementation.

Dr Robert Gamble next described the logistics for the review, including the program for the week, (which had been updated compared to what the review team had received). Also, he showed the review website, which (by mistake) had not been shared with the review team prior to the review.

Dr Andrew Applegate, NEFMC Staff, EBFM Plan Development Team Chair, introduced the EBFM development by the NEFMC; provided management context, how this meeting fits into their plans and how they expect to go forward with EBFM; how the Council evaluated initiatives elsewhere and decided on a Fisheries Ecosystem Plan based on fundamental properties of ecosystem (e.g., energy flow and predator/prey interactions). It was noted that the requested worked example need not be implemented, and that the Council through the EBMF PDT has devised a five-phase strategy with an initial example focus on the Georges Bank ecosystem; multispecies ecosystem models (under development); integrated ecosystem assessment; of functional groups or stock complexes; and of placed-based spatial management.

Dr Mike Fogarty presented the overall EBFM plan, the focus of which was on multispecies interactions and mixed species fisheries. He emphasized the danger of ignoring unintended consequences that had been mentioned, and noted for instance that MSY-based reference points depend on species interactions, that predation mortalities are time varying, indeed at times with surprises such as concurrent decreasing predation mortality for herring and increasing for mackerel. Dr Fogarty mentioned current practices with the NEFSC groundfish sector management areas and how the proposed Ecosystem Production Units (EPUs) may replace current single species management areas, which vary by species, and which are difficult to define and manage.

The proposed method offers a well-defined physical/oceanographic/Lower Trophic Level (LTL) approach to defining EPUs, but does not consider fisheries as implemented. Mike Fogarty expressed that this would be covered by later presentations.

ToR 1: EPUs were introduced by Dr Gamble, who described the procedure that was used for establishing the EPUs. It was noted that these units were quite similar to those developed for the Northeast Regional Ecosystem Plan in 1988, i.e., the approach is quite stable.

ToR 2: Ecosystem production potential was introduced by Dr Fogarty. It provides a simple approach to define fisheries production potential based on system production potential. There are only limited goals for how this is to be used, and the measure will be supplemented and supported by other approaches and lines of evidence.

The proposed approach builds on a detailed description of the LTL microbial loop, and a written comment on how this was specified was received from Dr Deborah Hart, NEFSC.

ToR 3 was introduced by Dr Sean Lucey after a lunch break. He described how Fisheries Functional Groups (FFGs) had been developed using cluster analysis – done before the introduction of groundfish sector management.

ToR 4: Dr Rick Bell presented Management Objectives and Performance Metrics, and discussed optimum yield. He noted that National Standard 1 allows using an aggregate approach to estimating the MSY of a fishery, and that according to National Standard 3, to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination. He further introduced the "strawman" strategic level objectives and the operational objectives.

ToR 5: Dr Fogarty introduced the suggested management reference points, and discussed historic MSY estimated for Northeast US continental shelf estimated 0.98Mt in 1973-76 from an aggregate surplus production model. The sum of single species MSY for the same area was 1.3Mt. He also presented Murawski's (2000) criteria for how to evaluate if an ecosystem is overfished. The questions after Dr Fogarty presentation were focused on why there should be an overall catch cap, when the species or FFG caps would likely shut down fisheries first, and it was discussed if the overall catch cap would be constant.

After a coffee break, there was a round of questions from the Review Panel, followed by a public question session. In the public session, Dr Sissenwine raised the question of high grading and noted that while this indeed may be a real problem, it shouldn't stop EBFM from being considered. Rather, the key question is if the EBFM strategy makes more sense than current practices.

Dr Howell noted that overfishing as a reference level means depleted, not necessarily that a stock is overfished. Capelin in the Barents Sea regularly goes below the overfishing level even without fishing, but fishing is the only handle we have on rebuilding.

The plenary meeting finished at 5 PM, after which the review panel held an *in-camera* session that finished at 6 PM.

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On Day 2 of the review, the chair opened the meeting at 9.00 AM with an overview of what happened the first day of the review and of the program for the rest of the meeting. There were 24 in the meeting room plus additional people on the conference phone when the meeting started.

ToR 6: Harvest Control Rules (HCRs) were introduced first by Dr Fogarty who gave an overview of the “strawman” HCRs that were developed for the initial analysis. The discussion among other things raised the issue of choke species and the difficulty in estimating unfished biomass (B_0).

ToR 7: The Hydra operating model was introduced by Dr Andy Beet, and the presentation also included the implementation of the assessment model in Hydra. The discussion after the presentation was intensive, and focused on multiple aspects of the model implementation.

Dr Gamble continued with a presentation of how the Kraken operating model was implemented. There were some concerns in the discussion that Kraken is not far enough along in its development for it to be evaluated properly.

After lunch, ToR 8, Assessment models, was introduced by Dr Fogarty, and he continued with ToR 9, the Hydra part of the simulation results.

There was an open question period and a public question period next, and the day’s meeting ended at 4.30 PM, followed by *in-camera* panel discussion.

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On the third day, Wednesday May 2, the meeting started at 9.00 AM with 24 in the room, and additional participants on the conference call line. Dr Kerr gave an overview of the day’s program.

Dr Geret DePiper started off with a presentation of the portfolio economic model as part of the materials for ToR 9. The ensuing discussion focused on the model implementation, early results, and if the portfolio model could be coupled with Hydra.

Next, Ms. Amanda Hart, UMass, Dartmouth, gave a presentation based on her M.Sc. work on evaluating an EBFM procedure for Georges Bank using ceilings on system removals. Ms. Hart used multispecies production models with a ceiling on system removals, indicator-based harvest control rules, and $\%F_{MSY}$ rules. The multispecies production model was modified somewhat from the one used as part of Kraken. The analyses were well-conducted and presented, and its tree analysis provided an interesting alternative representation of the usually complex output from HCR evaluation.

The rest of the morning was used for open question periods, which saw extensive and wide-ranging topics being raised. Keywords to illustrate this include:

- Research group size vs demands
- Overfishing at group or species levels, consequences?
- Are there strawman management objectives that are missing, and does inclusion of such require changes to model structure?
- Technical and biological interactions: any hope that an aggregating strategy can help alleviate problems with these interactions?
- B_0 issues
- Marine mammals/seals
- Stakeholder inputs
- Time lags in the operating models, data collected one year, assessment the next year, next year the quota, there's always a lag.

After lunch, there was a public question session, in which it was noted that the Council has to follow the Guidelines for National Standards, and manage on a single species basis. The National Standards are, however, under review.

Dr Sissenwine noted that time delay needs to be included in MPs; discussed the B_0 question, and on the big picture front noted that for multispecies approaches, we don't address where most of the trophic interactions occur, i.e., in the pre-recruits. We may not be able to model this on a species basis, but it is important. To what degree are the modelling approaches we're using now tying us to the past? It's conditioned on historical conditions, but that is not necessarily something desirable. We may be able to model/describe how ecosystems have developed, but we also need to make predictions. Its worrisome that we now pretend we can manage species at a single species MSY level and we're moving to another area that may not be more credible.

The public question period closed around 2.30 PM, and the review team spent the rest of the afternoon *in-camera*.

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The review team spent the entire fourth day, Thursday May 2, from 9.00 AM to 4.00 PM, discussing the review outcome and findings. Dr Fogarty was consulted several times during the day for questions to clarify aspects that the review team was uncertain about. The review team discussed findings for each of the ToRs in some detail in order to allow the Chair to get an early overview and notes of what would go in the summary report of the review.

Reviewers' Complementarity

The Chair, Dr Kerr, provides knowledge of the workings of the NEFMC and was familiar with regional questions, background, capabilities, and perspectives on management issues, which was important for the review. The three CIE reviewers have a diverse background and experience relevant to the theme of the review. In summary and very generalized, Dr Brander's strengths are in integrating ecosystem effects into fisheries assessment and management, Dr Howell has wide experience with multispecies models and implementation of MSE, and mine is in ecosystem modeling and development of EBM. During the review, we all participated in all activities, and we jointly discussed issues and findings. We discussed aspects of our findings and recommendations, and while we seemed in general agreement on all major points, we did not seek consensus.

NMFS Review Process

Independent reviews of the form conducted for NMFS by CIE are unique globally and provide independent evaluations of a character and quality that should serve as a model for other countries.

The procedure for conducting the reviews is well established and well organized by the NEFSC, and while the NEFSC-EDA branch has much less experience with CIE reviews than their assessment colleagues, the scientific parts of the review were well organized and conducted.

The present review suffered under the shutdown of the Government when the review was originally scheduled to take place in January of 2018. The review was thus postponed only hours before we were to leave for Woods Hole. Due to the required rescheduling of the review, many tasks had to be repeated in April. There were some minor glitches in the preparations for the review, likely due to the postponement, but overall, the review was a smooth operation, and I do not have specific suggestions for improvement of process or form.

Summary of Findings

General

Overfishing and overfished populations have been recurrent themes for the NEFSC for decades, back to the time of extensive foreign fishing in the 1960s and 1970s. There are notably problems with technical interactions in the ground fisheries, and we sensed an implicit hope during the review hearings that the introduction of EBFM might somehow, magically, help resolve those issues. That is, however, not likely (unless major changes happen concurrently), but EBFM may make it clearer what the involved tradeoffs are, and potentially set a path for addressing those. It is indeed an important aspect of EBFM implementation that it calls for a cooperation across traditional disciplinary boundaries as well as for cooperation with diverse stakeholder groups. Cooperation is indeed necessary for evaluation of tradeoffs, which must be based on data-rich information, transparent analysis, and with strong stakeholder involvement throughout the process.

For the review, the Council explicitly asked for guidance on whether the proposed tools and approach would provide them with the tools they need for implementation of EBFM. The overall conclusion, as detailed in the following sections, is that the required tools are not yet in place, even though considerable progress was demonstrated for the review.

I had the opportunity seven years ago to review the model development for EBFM at NEFSC, and among other things found about the research group:

> *"The NEFSC-EAP is a small and efficient group. Given the urgency that implementation of the new Ocean Policy Act calls for, and given the expanded scope of what is required to timely address key policy questions for spatial planning, EBM, and climate change, I strongly recommend that the NEFSC evaluates the resource allocation that implementation of the recommended NEFSC-EAP modeling strategy will call for. "*

I do not see, however, that much if anything has happened in the direction I recommended. I understand that the group currently involved in the reviewed EBFM development involves seven researchers, but with a combined effort level that corresponds to less than two person-years annually. I consider this vastly insufficient to the task at hand.

I further note, that introduction of EBFM is only part of the development that the Center is tasked with. And while this for the Council is of overarching concern, the National Ocean Policy establishes Ecosystem-Based Management (EBM) as a guiding principle, and marine spatial planning as a primary tool for ocean resource management in the United States (The White House, 2010). While I cannot evaluate what progress the Center is making toward multi-sectoral EBM, I note that there is need to develop capacity to evaluate the impact of, e.g., alternative energy production in ocean planning, and that this calls for spatial modeling capabilities that to my knowledge not are under development at the Center. Also, EBFM calls for spatial considerations, including for evaluation of MPAs, and the Center (to my knowledge) is not far with the development of tools for this. Atlantis could in principle be used, but as was expressed during the review, it is not in an operative state but will need considerable development for the purposes, including development of a specific spatial framework for the spatial questions that are to be evaluated. I would recommend the Center to consider alternative, simpler approaches; such do exist.

Finally, I note that climate change is becoming increasingly important for management of ocean resources, not the least for planning and consideration of adaptation. While such questions were not part of the review, it is an area that should be considered by the Center, e.g., in cooperation with climate modelers at the NOAA Geophysical Fluid Dynamics Laboratory and the Princeton Cooperative Lab. Further, this can be combined with the development of spatial modeling techniques as discussed above.

Objective 1: Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review was defined as a research-track review focused on specific aspects of a desktop Management Strategy Evaluation (MSE) implementation, which was intended to illustrate a plausible route for initial evaluation of harvest control rules (HCRs), and consider possible management options as part of an EBFM strategy for managed New England Fisheries.

The details of the proposed implementation review along with findings and recommendations are discussed under the following objective.

The review guidelines asked “for recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics.” Of these tasks, I have not addressed the question of “potential data inputs” as this was not addressed explicitly during the review, and it was not clear what the potential data inputs of concern were to be used for. A thorough evaluation of data inputs is a review in itself.

Objective 2: Review the proposed strategy for implementing EBFM on Georges Bank

The review as outlined was focused as a research track review of specific aspects of the implementation of EBFM rather than as a review of the overall strategy for EBFM. In essence, this means dealing with “how” questions for implementation, instead of “why” as for the choices that led to the specific MSE implementation at the NEFSC’s EDA branch.

It is pertinent, however, to also consider the “why” questions, given that NEFMC and NEFSC to my knowledge are breaking new ground by being the first to have CIE reviews of their EBFM strategy. I will therefore inject a bit of strategy consideration in this report, while concentrating on the research track of the draft implementation.

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

Ecological Production Units (EPUs) are proposed as management units to replace the current hierarchy of single species management areas, which varies by species, and which are complex to develop, manage and use in practice, not the least for industry.

The proposed method was presented in detail by Dr Gamble, and it offers a well-defined physical/oceanographic/lower trophic level (LTL) approach to defining EPUs. As implemented, it does not consider higher trophic levels (HTL) and fisheries. The main argument for not including HTL and fisheries in the EPU definitions is that these entities have changed considerable over the time period of concern. Hence, if EPUs were based on current conditions, they could not be relied on to be stable over time.

In contrast, the approach for defining EPUs based on physical/oceanographic/LTL has shown to be remarkably stable. The 2010 NEFMC White Paper on EBM (NEFMC SSC, 2010) presented an earlier version of the EPUs for the US Northeast Continental Shelf, and the changes based on new and updated analysis with additional data showed only small changes. The approach for defining EPUs can thus be considered stable, and my overall conclusion about it is that it is a sensible and well-defined approach.

The EPUs as defined provide an objective way of defining ecological boundaries, and given their stability, they may well be suitable for management purposes (as discussed further under ToR 3).

It may be considered a weakness that the EPUs do not consider the distribution of upper trophic level groups (notably fish) nor fisheries. Given, however, the variability of these entities, and that it is desirable to have management units that are stable over the medium to long-term, it seems that adoption of the EPUs as defined for this review is advisable.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

Dr Fogarty presented an approach for evaluating ecosystem production potential. This was a simple approach to define fisheries production potential based on system productivity. There were only limited suggestions for how this is to be used, and it will need to be supplemented and supported by other approaches and lines of evidence.

The main questions that are asked through the approach are:

- How efficiently is primary production transferred to higher trophic levels?
- Can this be used to set a cap for productivity? and
- Can this through monitoring be used to guide how exploitation should be modified due to changes in system productivity?

There have been numerous evaluations of the relationship between system primary production and fisheries production, dating back to Ryther's classic study (1969), with an illustrative more recent and developed application being published by Stock et al. (2017). The evaluations have as a common element that fisheries production potential (FPP) is estimated through a relationship of the type $FPP = PP \times TE^{TL-1}$, where PP is the primary production, TE the ecological transfer efficiency between trophic levels, TL, (typically 10%).

The approach presented at the review includes a detailed description of the LTL microbial loop, and has few details on the fish populations (upper trophic levels, UTL). Uncertainty is recognized and analyzed through a Monte Carlo approach, which is well done, but which does not consider structural uncertainty due to chain length, (which in turn is due to the aggregation of UTLs).

For illustration, the Summary Document for this review lists 11 piscivore species with trophic levels varying between 3.3 and 4.45 (ToR 3 - Appendix 3, NEFSC EDA, 2018). Assuming a 10% trophic transfer efficiency, this indicates a 14-fold (= $10^{4.45-3.3}$) difference in production efficiency between the lowest TL and highest TL species within the piscivore guild. It follows, that the average production efficiency of the piscivore guild will be <u>very</u> dependent on the biomass distribution by species, and that the absolute measure can be indicative only – while trends may be more informative.

Further, the estimate of guild productivity obtained from this method includes all fish species within guilds, exploited as well as non-exploited and non-exploitable species. As such, even if the estimates were precise, they would indicate latent productivity, and as such not be directly useable to provide caps for realizable productivity.

The overall conclusion is that the projections of ecosystem production potential from primary production in this study are highly uncertain – as is indeed always the case for this form for projections. It is worth noting, however, that there is excellent information available about primary production in the New England area (as compared to many other areas), and that there indeed is useful information in this.

A key question then is, how will the primary productivity and microplankton abundance change over time? We have seen in numerous ecosystem studies that changes in environmental productivity can have amplified, non-linear impacts on HTL (Christensen and Walters, 2011). Assuming further, that the microbial loop doesn't show major structural changes over time, it seems fair to use changes in environmental productivity as indicators for how the fisheries production may change, at least in a directional sense.

Tracking changes in environmental productivity may thus be useful for providing context, and possibly even connecting such trends to exploitation trends. If, e.g., the indications are that environmental productivity is decreasing, it should set off alarm signals that fish productivity may be declining as well, calling for more caution in quota setting – or vice versa.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units

There are considerable problems with the management of multispecies fisheries in the New England area, and this has unintended ecological, economic, and social consequences. On this background, it is timely to give the problem a fresh look to consider:

- Can the spatial management units be better defined? and
- Can fisheries be categorized so that biological and technical interactions are considered more appropriately in the management?

The first of these questions was evaluated in ToR 1, where the conclusion was that EPUs could indeed be defined so as to fit with ecological productivity patterns. Hence, the present ToR (3) is designed to evaluate how fisheries can be categorized more appropriately.

Internationally, the question of how to handle biological and technical interactions have led to categorization of what is here called Fisheries Functional Groups (FFG) or what (especially in Europe) is called métiers (e.g., Ulrich et al., 2001). The aim being to better manage effects due to competitive externalities such as competition for shared resources and fishing grounds. In the NEFSC-EDA application to Georges Bank, the FFGs were defined as "species that are caught together, have similar life history characteristics, and play similar roles in the transfer of energy in the system". As such, the FFGs have two dimensions (fleet – fish species), and indeed corresponds closely to what elsewhere is called métiers.

For the Georges Bank, Dr Lucey presented an overview of how FFGs can be developed as operational fisheries units based vessel trip reports (VTRs) of landings, species caught and area fished in New England fisheries. Landings were combined into spatial and temporal units based on fishing gear categories, segregated by vessel size and species caught, after which k-means clustering was used for FFG categorization. The approach as presented has been described more fully in a journal publication by Lucey and Fogarty (2013), an interesting and well conducted study.

The example presented at the review, was intended to illustrate how clusters could be mapped onto real fisheries. As an example, otter trawl fisheries were categorized in ten clusters, some of which were fishing only one species, (e.g., shrimp) others as many as ten. As for the mapping of these clusters, Dr Applegate, NEFMC, expressed confidence that the clusters could be mapped clearly onto defined fleets. This is promising, and indeed in agreement with experience from elsewhere (e.g., Mackinson et al., 2018).

Yet, it remains to be evaluated how the FFGs map on to the entire fishing operations for each of the EPUs as well as for the groupings used for the New England Groundfish Management Sectors.

The analysis presented a number of cases where the spatial clusters were grouped within EPUs, notably for Georges Bank, but it was also clear that this was not always the case. As an example, the diverse Otter Trawl Cluster 1 while having substantial representation on Georges Bank spilled over to the Gulf of Maine. This was seemingly due to groundfish seeking deeper, warmer water in the colder months. This illustrates an unavoidable problem, EPUs cannot be defined so as to unequivocally represent FFGs/métiers. There will be cases where occurrence spreads out over EPUs and will call for shared management within and between management councils.

Still, well-defined FFGs can help alleviate such issues, and it will be interesting to see further work on the topic, including mapping onto the New England Groundfish Clusters and other actual fisheries management units.

Also, FFGs will change over time as fisheries evolve and fish populations change. This will call for periodic reanalysis and updates.

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

The following "strawman" objectives for the strategic level of the proposed EBFM in preparation for the CIE review were defined in a presentation given by Dr Bell as:

- Maintain/restore sustainable production levels
- Maintain/restore biomass levels
- Maintain/restore functional trophic structure

These strawman objectives are, as strategic objectives should be, broad and oriented at the mid-term, i.e., typically with a 5-10 years' time horizon, depending on species dynamics. They cover, as they should, the key aspects, i.e,. keeping productivity at levels where yield is maximized and where populations have a healthy buffer size (without growing to an unproductive level), and maintaining biodiversity.

The strategic objectives are not explicit on social and economic strategic objectives (though it may to some degree be implicit in the maintenance/restoration of sustainable production levels). I presume, however, this is the intention, given the wording of a strategic objective defined by NEFMC's SSC (2010): "Protect ecosystem structure and function to allow optimal harvest for fishing communities and future generations". It may thus be pertinent to make this explicit in the strategic objectives.

The strategic objectives, being "strawman" fall short on a few other aspects. As an example, the management objectives for the North Pacific FMC ground fisheries[2] are far more wide-ranging:

> *"prevent overfishing, promote sustainable fisheries and communities, preserve the food web, manage incidental catch and reduce bycatch and waste, avoid impacts to seabirds and marine mammals, reduce and avoid impacts to habitat, promote equitable and efficient use of fishery resources, increase Alaska Native consultation, and improve data quality, monitoring and enforcement."*

A critical aspect is how the strategic objectives are to be operationalized. For this, the following associated operational objectives were defined as:

- Maintain habitat productivity
- Ensure that F is below threshold
- Minimize the risk of permanent impacts on vulnerable components

For operational objectives, the above are quite general and rudimentary, and it is not clear how they will be translated into measurable objectives and performance metrics – likely because the analyses as presented are representative only, and not intended to be complete with regards to specificity. A notable omission is that they do not include social or economic metrics.

I take it for granted that the actual operational objectives, once implemented will follow more closely what is done for management elsewhere – NPFMC may be a good example.

[2] https://www.npfmc.org/management-policies/

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

Dr Fogarty made a presentation about ecosystem-based reference points, in which he outlined the proposed schedule as used for the Hydra simulations. They consist of:

- An overall catch cap (ceiling), based on system productivity
- Ceilings for catch by individual FFGs with their sum not to exceed the overall cap
- Biomass floors:
    - For FFGs the total biomass is not to fall below 20% B_0
    - For individual fish species, their biomass is not to fall below 20% B_0

The overall catch cap was proposed to be based on system productivity. As discussed for ToR 2, the methods for estimating fisheries production from primary productivity are highly uncertain, and I do not recommend such a procedure for setting hard caps. From discussion during the review, it further seemed that the catch ceiling estimated from productivity was unlikely to be reached – which raises the question, why have a ceiling that is unlikely to be reached.

Ceilings by FFGs would be more specific, but it was not clear from the review how these ceilings would be set in the real world. Here, there would be a large number of FFGs, and setting the ceilings would likely involve estimation of an MSY level by species, then allocating each species across FFGs, and finally summing up the maximum catches by FFG. It, thus, also involves setting catch shares across FFGs.

Some alternative ways of estimating maximum exploitation rate (for ceilings) were presented at the review. One was derived from Iverson (1990) and Ware (2000) and expressed “exploitation rate should not exceed the fraction of microplankton production in the system”. This relationship is, however, not well established or defined (microplankton?). As it also seems difficult to both parameterize and evaluate, I do not think that it is a suitable measure for actual use as it stands.

Another measure, by Moiseev (1994) proposed that the ecosystem exploitation rate should not exceed 20%, (which seems a reasonable safe level based on Iverson, 1990), and Iverson (1990) suggested that exploitation rates (fisheries and predation combined) should not exceed the ratio of new primary production to total primary production (the *f*-ratio) in marine systems.

The core problems with rules such as outlined above are that the methods are uncertain, and that the rules are difficult to communicate to and get acceptance for from stakeholders. It seems that it easily becomes a "trust me, I am a highly trained expert …" – indicators should be reliable and easy to explain.

It may potentially (as pointed out by Dr Fogarty) be possible to empirically calculate FFG ceilings by aggregating all species in FFGs, and plotting yield vs effort (from VTR data) to obtain estimates of max yield by FFGs. Such would be historically based and it would be necessary to consider how representative they would be for later time periods.

My sentiment for the catch caps (ceilings) is that they should rather be used as a reference level (max catch as estimated from MSY analysis, e.g., 75% of F_{MSY}) giving the maximum exploitation rate that can be applied when biomasses exceed the upper reference threshold.

The biomass floors are in principle reasonable, but not without issues. A biomass floor by FFGs thus calls for two rather impossible measures, (1) the biomass of the part of the overall species biomasses that are included in a given FFG, and (2) how to estimate the unfished biomass (B_0) for such a species/fleet grouping. Add to this, that the calculation of B_0 always is uncertain, given its model dependence.

The biomass floors are to be used to set overfishing levels for species (and by splitting and summing up, by FFGs as well). Given the uncertainties associated with estimating B_0 and splitting these across FFGs, it is reasonable to consider if there may be alternative methods for evaluating overfishing (and target fishing rates). Related, Dr Fogarty raised this question if NEFSC research vessel surveys could be used to provide a basis for determination of target fishing rates and overfished status. While interesting propositions, translating biomass/tows into fishing rates and biomass status would involve a number of assumptions, which have not been specified.

Overall, the biomass floors are reasonable to use in the Hydra demonstration, but it is very unclear how and if they can be convincingly implemented in real world applications.

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

Dr Fogarty gave an overview of the harvest control rules (HCR) as implemented in the Hydra simulation structure with the proposed floors and ceilings approach. The overall cap is to "provide a context based on energetics, if we set it appropriately is should not or seldom be breached"; "if it is breached, it is a clear warning that remedy measures should be taken". The floor for FFGs was – as expected – found to be less conservative than for individual species.

Dr Fogarty further provided an overview of the HCRs, and I conclude that these are well-defined for the specific use, i.e., to evaluate a range of possibilities. I do, however, not consider that the HCRs as defined are suited for actual implementation in real world MSEs; their use is limited to an initial evaluation of characteristics. Notably, the use of step functions would not work in actual evaluations. Building on what is done elsewhere would be warranted.

Also, for actual MSE evaluations, it would be worthwhile to compare evaluations of HCRs to single species management rules, other ecosystem management rules, and also some mixed version.

As discussed under ToR 5, I would recommend evaluating the performance of reference points based on the current NEFMC procedure for estimating ABLs, i.e. ceilings at MSY, targets at 75% MSY. It would also be pertinent to consider that when below the limit reference points, fishing cannot be assumed to go to zero, but rather a suitable low level (for instance F=0.04 year^{-1} as in Mackinson et al., 2018).

ToR 7: Review the structure and application of operating models for Georges Bank.

Hydra

Dr Beet gave a presentation about the structure and application of operating models with focus on the Hydra implementation. Hydra is a multispecies model with technical and (partial) biological interactions. As implemented, it has ten fish species and three fishing fleets, and the fish species have size structure, which determines interactions and catchabilities. Predation is size selective (for which, Ursin, 1973 is a good reference).

Stock-recruitment relationships are not pre-defined, but initial hockey-stick models are obtained from data fitting, and these initial S/R models are subsequently resampled so as to obtain viable (non-crashed) populations throughout the system. The S/R model and resampling scheme is in principle a neat idea and implementation, but not without issues.

One issue is that hockey-stick recruitment models have two parts, when below the change-point (δ, the level of spawning stock biomass, SSB, at which the slope changes), recruitment is a linear increasing function of SSB, above recruitment is either constant or linearly changing. At the change-point there will usually be a sharp bend, which can lead to numerical problems (Barrowman and Myers, 2000). Given this, it may be worth considering a logistic or generalized hockey-stick to minimize the problems.

Hockey-stick S/R models tend to produce lower compensation than B&H S/R models at low SSB densities (Barrowman and Myers, 2000), which isn't surprising given that the hockey-stick form does not have density dependence at low spawning biomasses. The logistic hockey-stick model also has a broader range of spawning biomass over which density dependence occurs. Indeed the consequence of the hockey-stick linear relationship is a constant recruit/spawner ratio (and hence survival to recruitment) at low spawning biomass (Hilborn and Walters, 1992, pp. 248-9). This can cause instability, and provides another argument for using a range of S/R relationships when exploring the performance of HCRs.

Hydra is implemented as a full MSE model with operating and assessment model coupled in a framework, much in line with common practice (Punt et al., 2014). The operating model has species interactions where consumers' intake set predation mortality rates for prey, but where predators growth rates are constant – predators always get their model, they are "efficient predators" (Butterworth and Plaganyi, 2004). An implication of this model structure is that it is known to cause instability when moving away from the base situation, e.g., when introducing major changes in fishing effort.

Such instability is likely an issue for the Hydra implementation. I note from the resampling of S/R models (Figure 4.4 in NEFSC EDA, 2018) that all of the "plausible" resampled models for all ten species have higher compensation ratio than the initial S/R models. This indicates that the compensation ratios had to be increased to avoid population crashes. This assumption is in line with Figure 2 in Gaichas et al. (2016), the core Hydra publication, which for a simulation aimed at estimating unfished biomass shows major instability with 5-10 year cycling patterns indicated for many species. I presume based on the figure, that the model is unstable, and that whenever a species crashes, it quickly rebounds because of the high compensation ratios, leading to instability with medium-term cycling.

The Hydra model structure is in line with similar approaches and has the advantage of being developed in-house, and thus targeted to the specific application, but details of the implementation aspects are not clear from the available materials. This is indeed a problem with using a newly developed model, and, as one of the developers stated during the review, the code "needs to be cleaned up a little bit". Also, I'm surprised that the Hydra model was reported as "slow to run" given that ADMB is not used for optimizations as implemented.

While the in-house development has some clear advantages, it also has issues. Best practices for MSE (Punt et al., 2014) thus recommends to "base the operating model(s) and the management strategy on software that has been developed for broad application and has been tested extensively." The main implication of using in-house software is that such will need to be tested much more thoroughly, starting at the level, does it do what it is supposed to do when there's no variability?

Overall, my conclusion regarding Hydra is that it is an interesting model, and that it needs refinement before it can be used in a credible manner to evaluate realistic HCRs.

Kraken

Kraken builds on a multi-species production model, and is implemented with group definitions that follows those of the Hydra model. While Kraken was described as an operating model, it is actually developed with a coupled optimization model based on economic portfolio techniques, which are also developed in-house ("Applying Portfolio Management to Implement Ecosystem-Based Fishery Management (EBFM)," 2016).

The implementation is still work in progress – as was expressed during Dr Gamble's presentation, which among others called for more robust estimation routines, more realistic fleet structure, simulations to compare current management strategies with portfolio model, and simulations with misspecified reference points.

The present implementation relies heavily on the Hydra implementation to which Kraken was tuned. Given that a major advantage of having several operating models is that they can provide independence from model structure, it seems unfortunate that the Kraken model had to be tuned to Hydra results.

The Kraken model has, as does Hydra, ten species, which were aggregated in three functional groups, and the linking of the Kraken operating models to the portfolio model was through biomass, species floor (0.2 x unfished) and functional group ceiling (0.18 * functional group biomass). Work on adding fleet structure to Kraken was reported in progress, but not operational.

Dr Gamble presented results for predicted catches and predator removals of prey (and could also show diet compositions over time). These plots could be compared to actual catches and known diet compositions, but this had not been done yet.

The economic optimizations presently consider only revenue, not cost. Currently, this limitation was because of difficulty standardizing costs across fisheries/species, so they were left out of initial analysis. This is, however, a major constraint, as maximization of revenue by itself isn't a suitable objective for fisheries.

It was noted that the current portfolio implementation should be considered at the proof of concept level only. Also, it is currently only linked to the Kraken multispecies production models, but could be coupled to other models notably Hydra.

The limited implementation of the Kraken model complex makes evaluation of its potential for use as part of the EBFM process difficult, or rather it is not possible to evaluate this at present. Some general conclusions can, however, be drawn:

- The modeling complex is interesting and builds on techniques with well-known characteristics.
- The optimizations build on an objective function, which will need to be defined in a process involving the Council and stakeholders.
- Given that the optimizations may well involve strong tradeoffs, it is unlikely that they will ever be used to set actual management objectives.
- The optimizations can, however, be used to provide reference levels for notably revenue (but likely other economic parameters as well, e.g., net revenue, jobs). These reference levels can, in turn, be used for scaling when evaluating results from HCR evaluations.

Operating models, overall

The present exploratory evaluation of HCRs and steps towards EBFM relies on the use of two operating models, which is very much in line with best practices of using multiple models (Punt et al., 2014). Generally, however, it is assumed that the operating models are used to evaluate the same set of HCRs, and this has not been the intention with the NEFSC-EDA draft implementation. I think it would be worth considering if it is possible, i.e., to also use Kraken for HCR evaluation, similar to what's (intended to be) done for the Hydra model.

A question was raised if ten was the right number of fish species to include in the evaluations. In reply, we heard that it wasn't really possible to go further with the Kraken model, and we expect the answer to be somewhat similar for Hydra. Diversity is good, as is model ensemble approaches.

Given what has been developed in NEFSC-EDA, the possibility was raised during a question session of the review: why the NEUS Atlantis model had not been used as an operating model for evaluating HCRs? The Atlantis model was designed to be an operating model for MSE, and it was noted that the Center over the last decade has extended considerable resources to the Atlantis development. The answer we received was that "Atlantis is not currently operational and we don't trust it for use here. Also, it is not practical to include any form for stochasticity." It was described that the NEUS Atlantis model currently is undergoing a major revamp and update. I note that when I reviewed the NEFSC EBFM models in 2011, I wrote "The NEUS Atlantis model, which resource-wise is the biggest investment of the [group] has after five years of development not reached a state where it can provide credible output". Seven years later this still holds.

NEFSC-EDA has also worked extensively to develop its own implementations of the EwE approach (EMAX and R-path), and it was mentioned by Dr Lucey that he will be working with an MSE approach with Dr Punt in the near future, based on adding MSE capabilities to R-Path. I can only recommend this, noting that a corresponding North Sea MSE study using EwE combined with a MSE routine developed at CEFAS has reached a state where it can convincingly be used as part of EBFM (Mackinson et al., 2018). Indeed, the North Sea application has reached far beyond the work reviewed here.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

To set the stage, assessments in the NEFMC management have changed to increasingly use survey index methods, which by now are used for a majority (22) of the managed species (39). In addition, 14 are age-based, two length-based, and there's one "other" methodology. The limited use of methods-based assessments was described during the review as being due to consistent problems with retrospective analysis.

For the review's ToR 8, Dr Fogarty gave an overview of assessment models and required data. In total, three simulated assessment models had been implemented in connection with the Hydra operating model:

1. Model-free simulated survey index
2. Multi-species production model
3. Multi-species delay-difference model

The model data requirements are much lower for these model types than for, e.g., corresponding age-based models. We did, however, not discuss data availability or requirements in any detail during the review, and I refrain from commenting on data availability and sources as part of the review due to lack of experience with New England fisheries.

The aim with these multispecies assessment is to evaluate how well they perform. The finding, as reported by Dr Fogarty was that the more complex delay-difference model (#3) did not behave much better than the simpler production model (#2). While this may seem surprising, it is, however, aligned with earlier findings that a simpler model often outperforms a more complex one when it comes to making predictions (Ludwig and Walters, 1985).

I consider the choice of assessment models pertinent, for the purpose of evaluating HCRs there is no need to implement the actual assessment models that will be used for actual quota settings.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

An interesting question when evaluating management procedures is if the underlying operating models have to be realistic for the HCR evaluations to be credible. There are diverging opinions about whether this is a requirement. Some of the overall best practice requirements for operating models (Punt et al., 2014) are:

- Use of more than one operating model
- Set parameters from fitting to data
- Consistency with reality with regards to model performance

Where the last item points towards a requirement for realistic model behavior, and such a view was also expressed at the review by Dr Applegate, it is questionable, however, if the modeling complexes reviewed here have reached this state.

For the Hydra MSE simulations, I especially noted that the piscivores and elasmobranchs showed little sensitivity to fishing, while planktivores were very sensitive and collapsed at seemingly low fishing pressure. During a question session at the review, it was expressed that this model behavior was linked to how the models were parameterized, notably with regards to biomass levels and fishing pressure. That may well be the cause, but it raises a question about how the results can be evaluated at least in the present round.

Still, some of the very preliminary results seem to make sense, e.g., that ramp down of exploitation rate improves the general situation, and that using individual floors results in better protection than using floors by FFGs.

Overall in the simulations as presented, there were too many things happening in one go, which makes it difficult to understand why reactions were as they were. I would prefer more simulations where only one factor was changed at the time to be able to better evaluate the findings. But, the bottom line is that one cannot evaluate the performance of the implemented HCRs from the model runs with the current model and MSE implementation.

As discussed earlier, I do not think the overall ceiling, i.e., the overall system catch cap, can be defined objectively from productivity calculations. The inherent uncertainty is too big. If such a ceiling is to be implemented, it should be for precautionary management considerations, and the level should be a management decision – perhaps with the ecological evaluations as guide.

For the HCR evaluations, my recommendation would be to use the system and FFG ceilings as reference points as part of an exploration of the maximum allowable exploitation levels.

With regards to the portfolio simulations, it is clear that co-variance between landings is important for how managers can manage risk, and hence evaluations of this should be encouraged. Co-variance is time-variant, and it is interesting that the NEFSC team has developed a portfolio analysis to hedge value of landing through mean-variance tradeoff analysis, built on an optimization analysis. The analysis as described above, builds on coupling of biological and portfolio models with three constraints, 1 revenue target, 2, species floor (0.2 x Bo) and guild ceiling (0.18 x guild sum), and the optimization involves tradeoffs between fisheries, species and guilds.

One aspect of the coupled portfolio results was that there was higher variability in catches in optimized runs, which to some extent was due to comparison with a period with low stocks and catches. Further, it was due to moving toward equilibrium states, but not reaching it.

For the results, I would suggest to show not just relative results by species (which were unnamed on plots), but also overall and absolute results, e.g., as stacked bar plots over time summarizing across the ecosystem.

While I laud the analysis and optimizations, I do think the main application of portfolio methods will be to provide reference points for how far it would be possible to go. It's not likely to be used to give directions for where we should go.

Conclusions and Recommendations

The group of scientists in the NEFSC-EAP is very capable, but are faced with a major task in developing procedures for actual implementation of EBFM. There are no clear models for how this should be done from other NOAA Centers, and it is not a simple task when it has to be done to the level and scrutiny required by Fisheries Management Councils.

For the present review, my overall conclusion is that a lot of good work has been done, but the overall strategy is not ready for evaluation or implementation of EBFM by NEFMC. Yet, there is considerable progress, as summarized next by ToR:

- ToR 1, Ecological Production Units: These are ecologically well-defined and likely to be stable. I recommend that they be considered as substitution for the elaborate spatial scheme used currently for individual species.
- ToR 2, Ecosystem Productivity: Tracking productivity is not likely to be useful for objectively setting ecosystem-level caps for exploitation given the inherent

uncertainty involved, but may indeed be useful for evaluating trends for exploitation pressure.

- ToR 3, Fishery Functional Groups: The FFGs are well-defined and potentially useful for operationalization, and I do recommend that they be evaluated at the full scale of interest for NEFMC. It remains, however, to be seen if there will be too many cases where quota sharing between FFGs will cause problems, and the extent to which the FFG will map onto NE Groundfish Management Sectors is unknown. It is noted that EPUs (ToR 1) will only partly be aligned with FFG spatial distributions, and this in some cases will call for shared management within and between Councils.
- ToR 4, Strawman management objectives: These strategic objectives fall somewhat short as defined, and the associated operational objectives are quite general and rudimentary, and it is not defined how they will be mapped to measurable objectives and performance statistics. Notably, social and economic metrics are not (yet) considered. My recommendation is obvious: follow best practices from other Councils.
- ToR 5, Management reference points: I think the proposed "ceilings" should rather be used as reference levels than as absolute catch caps, given the inherent uncertainty involved, and the prospects for high-grading. In essence, I do not think an overall cap will be useful, unless it is set so low as to be invoked regularly. If so, it may improve the overfished situation, but my preference would be for this to happen with focus on the overfished species, rather than through an overall ecosystem catch cap.

  The biomass floors are in principle reasonable, notably, it is unclear how well and effective they can be set at the FFG level. I do, however, encourage the further development of FFG biomass floors as these may well show to be useful for management (and industry) at the FG level. The most efficient floors are those defined for individual species, and they should be included at least for the core species, including species of special concern.
- ToR 6, Harvest Control Rules: The HCRs presented at the review were suitable for the initial cursory implementation, but not for actual implementation. Also, given that the operating models are not yet at a stage where I find them credible for the HCR evaluations, there clearly is more work to be done on these issues.
- ToR 7, Operating models: Both the Hydra and the Kraken models will need further development before they can be used convincingly to evaluate HCRs. I recommend a multi operating model approach for the evaluations, including with the use of models with different layers of complexity (including more species and fleet resolution).

  The economic optimizations are interesting, and it is good to see economic considerations involved. Such along with social aspects should indeed be included in all analysis related to EBFM in order to better evaluate the properties of tradeoffs. The economic optimizations can be useful for providing reference points, rather than to provide targets for management. Also, the economic optimizations provide information about co-variance between landings, which may be useful for risk management.

- ToR 8, Assessment models: The assessment models implemented are simple (as they should be), and do not require extensive data input. The choice of assessment models is reasonable, and they are useful for further evaluations.
- ToR 9, Simulation tests: I don't find the characteristics of the operating models realistic as implemented, and this has implications for how I view the outcome of the simulations. While some of the results from the simulations are sensible, my overall conclusion is that the simulation testing is not at a stage where the results can be evaluated in a credible manner.

Overall, one cannot evaluate the performance of the implemented HCRs from the model runs with the current model and MSE implementation – which, I gather, wasn't the intention either.

The NEFSC-EDA group is capable, and is doing pioneering work on implementation of EBFM. Still, my conclusion is that the resources that are assigned to the task are vastly insufficient for full and credible development. The implementation of the preliminary pilot study has not received a level where it credibly can be used to evaluate how EBFM should be implemented or what the consequences of the implementation might be. The work that has been done, however, represents a significant step on the way towards EBFM, and for this it should be complimented.

The perhaps key question asked of the review panel several times during the review was if we thought the research was on the right track. That's a different question to answer; there clearly has been planning behind the strategy that is partly implemented at NEFSC-EDA, but the rationale for the pilot implementation of especially ToR 4-9 was not clear. I recognize the tendency within NMFS in general for developing in-house approaches, but also that requires substantial personnel resources for full implementation, and the staffing of NEFSC-EDA that is allocated to EBFM is rudimentary and seemingly not sufficient for this – we heard that less than two person-years annually was allocated. I also note the best practice guidelines for MSE (Punt et al., 2014), which recommend to "base the operating model(s) and the management strategy on software that has been developed for broad application and has been tested extensively." I find it likely that this would be more efficient than development of new methodologies.

Looking beyond the immediate requirement of NEFMC for implementation of EBFM, I also note that the NEFSC-EDA website[3] mentions that "the foundation for Ecosystem Based Management is now being developed and refined". With reference to the National Ocean Policy (The White House, 2010) the "need to establish the scientific architecture in support of EBM in the region to meet […] emerging challenges and opportunities" is recognized. This need is for EBM (not EBFM only), and I feel inclined to cite my report from the 2011 EBFM review at NEFSC:

"To guide the NEFSC toward implementation of EBM my most important recommendation is that the NEFSC-[EDA then EAP] takes on the role of an interdisciplinary unit that can foster broad modeling initiatives and cooperation. An important aspect of this should be to define a clear and explicit policy-driven strategy for what modeling to conduct in order to implement EBM at the NEFSC. "

"For the strategy-development, it may serve to develop a number of over-arching, yet specific questions, to help define the required modeling capabilities. Examples that go beyond what is currently considered by [EDA] could be:

- How does land-use patterns (including nutrient runoff) impact productivity of key LMR?
- What are the ecological impacts of bottom-modifying gear and how can the impacts be minimized considering economic and social impacts?
- How does current and alternative fisheries management impact non-target species, e.g., those under the Endangered Species Act (ESA)?
- What are the potential consequences of developing a large wind farm in NEUS, and where would the impact be minimized?
- What are the potential ecological impacts of oil exploration (and potential spills) in New England marine waters?
- How will the LMR populations and their productivity in NEUS be in 2020 and 2050? What adaptations are possible? "

While I do not have a clear overview of what NEFSC has done and is doing to implement EBM, I have not seen indications that the Center is much closer to this than they were seven years ago.

I recognize that the NEFSC-EDA is a small and efficient branch with very limited staffing dedicated to EBFM/EBM, and conclude that for successful implementation of the National Ocean Policy Act, an expended scope is required to address key policy questions related to spatial planning, EBM and climate change adaptation. I therefore strongly recommend

[3] https://www.nefsc.noaa.gov/ecosys/

that the NEFSC evaluates the resource allocation that implementation of EBFM, and indeed of the overall EBM modeling strategy will call for.

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Appendix 1: Bibliography of materials provided for review

NEFSC Ecosystem Modeling Review
Background Readings

The main document provided for reviewed by the Panel was an overview of the EBFM management procedure:

NEFSC Fishery Ecosystem Dynamics Assessment Branch. 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. April 20-May 2, 2018, Woods Hole, MA. https://www.nefsc.noaa.gov/program_review/docs/Georges%20Bank%20EBFM%20Summary%20Document.pdf.

In addition, the following background materials were reviewed by the Panel:

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Presentations for Review

Presentations covered the following topics were reviewed by the Panel during the in-person meeting:

1. Objectives for the Review (Mike Simpkins, NEFSC)
2. Logistics (Rob Gamble, NEFSC)
3. NEFMC Ecosystem-Based Fisheries Management Plan Development Team (Andrew Applegate, NEFMC)
4. Background and Overview of Proposed Management Procedure (Mike Fogarty, NEFSC)
5. Defining Ecological Production Units (Robert Gamble, NEFSC)
6. Ecosystem Production Potential (Michael Fogarty, NEFSC and Kimberly Hyde, NEFSC)
7. Defining Fisheries Functional Groups (Sean Lucey, NEFSC and Mike Fogarty, NEFSC)
8. Strawman Management Objectives and Performance Metrics (Richard Bell, The Nature Conservancy)
9. Ecosystem-Based Reference Points (Mike Fogarty, NEFSC)
10. Harvest Control Rules (Mike Fogarty, NEFSC)
11. Structure and Application of Operating Models -- Part 2 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

12. Structure and Application of Operating Models --Part 2 Kraken (Robert Gamble, NEFSC and Geret DePiper, NEFSC)
13. Structure and Application of Assessment Models (Charles Perretti, NEFSC and Mike Fogarty, NEFSC)
14. Simulation Tests and Performance Management Procedure -- Part 1 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)
15. Simulation Tests and Performance Management Procedure -- Part 2 Kraken (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

Appendix 2: CIE Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Ecosystem Based Fishery Management Strategy Review

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevenson Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the base scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

Ecosystem Based Fishery Management (EBFM) Strategy Review

Objective: Review a proposed implementation of EBFM for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the NEFMC. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC management objectives, as well as evaluate an “operating model” intended to simulate the performance of the EBFM procedure. The “operating model” in this case is a multi-model suite that can include empirical approaches as well as simulation models. The reviewers will be asked to provide recommendations to improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) review process).

The review will encompass the EBFM procedure, the suite of operating models, and a worked example of quota advice as they pertain to fisheries management in the Northeast region. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group, Overfishing Limits (OFLs), potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Reviewer Requirements

NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the SOW, OMB Guidelines, and the TORs below. The reviewers should have working knowledge and recent experience in ecosystem-based fishery management particularly in areas of Management Strategy Evaluation/Management Procedures, Fishery Ecosystem Plans, Integrated Ecosystem Assessments, ecosystem models, multi-species models, population dynamics, harvest strategies, and fisheries management regulations as they apply to EBFM. We prefer having at least one international reviewer and at least one reviewer from the U.S. The third reviewer can be an international or U.S reviewer.

Tasks for Reviewers

- Review background materials and reports prior to the review meeting related to the Terms of Reference.
- Attend and participate in the panel review meeting
  - The meeting will consist of presentations by NOAA and other scientists, and other experts to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreignnational-registration-system.html . The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at Northeast Fisheries Science Center Woods Hole, MA

Period of Performance

The period of performance shall be from the time of award through March 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
April/May 2018	Panel review meeting
Approximately 3 weeks later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
Robert Gamble
166 Water Street
Woods Hole, MA 02543
robert.gamble@noaa.gov

Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review

   Appendix 2: A copy of the CIE Statement of Work

   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Final Terms of Reference
Ecosystem Based Fishery Management Strategy Review
April 30-May 3, 2018
NOAA Fisheries/Clark Conference Room
Woods Hole MA

Objective 1

Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the New England Fishery Management Council. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC strawman management objectives as well as evaluate a worked example intended to simulate the performance of the EBFM procedure. (The strawman objectives were used to develop the EBFM strategy and framework; final objectives will be developed and approved by the NEFMC at a later date.)

The reviewers will be asked to provide recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a SAW/SARC assessment review).

The review will encompass the EBFM procedure, the potential operating models used to test the procedure, and a worked example of the relative performance of the EBFM procedure for providing quota advice as they pertain to fisheries management of Georges Bank fisheries.

If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group OFLs, potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Objective 2

Review the proposed strategy for implementing EBFM on Georges Bank

Terms of Reference

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

Appendix 3: Panel Membership or other pertinent information from the panel review meeting

The review panel consisted of,

- Dr Lisa Kerr, (Chair), Research Scientist at the Gulf of Maine Research Institute, Portland Maine and Vice Chair of the NEFMC Science and Statistical Committee
- Dr Keith Brander, Senior Scientist Emeritus, Danish Technical University Aqua, Lyngby, Denmark, who has expertise in integrating ecosystem effects into fisheries assessment and management
- Dr Daniel Howell, Fisheries Mathematical Modeller, Institute of Marine Research, Bergen, Norway with expertise in multi-species modeling and management strategy evaluation
- Dr Villy Christensen, Professor at The University of British Columbia, Vancouver, Canada, with expertise in ecosystem modeling and EBM.

Dr Kerr facilitated the review, including the public sessions, the *in-camera* sessions of the review panel, and its meetings with key contacts at NEFSC. Several scientists from NEFSC/EDAB and other institutions made presentations at the review, notably Dr Mike Fogarty, Dr Robert Gamble, and Dr Andy Beet.

The following registered as participants in the review meeting over the three days of panel presentations,

Name	Affiliation	E-Mail
Michael Fogarty	NEFSC/EDAB	michael.fogarty@noaa.gov
Robert Gamble	NEFSC/EDAB	robert.gamble@noaa.gov
Mary Kavanagh	Kavanagh Fisheries	MBYPAT@aol.com
Laurel Smith	NEFSC/EDAB	laurel.smith@noaa.gov
Robert Hildermith	UMass Dartmouth	rhildreth@umassd.edu
Sean Lucey	NEFSC/EDAB	sean.lucey@noaa.gov
Charles Adams	NEFSC/EDAB	charles.adams@noaa.gov
George Lapointe	Fisheries Survival Fund	georgelapointe@gmail.com
Wendy Morrison	NMFS/SF HQ	wendy.morrison@noaa.gov
Anne Richards	NEFSC	anne.richards@noaa.gov
Scott Large	NEFSC	scott.large@noaa.gov
Andrew Applegate	NEFMC	aapplegate@nefmc.org
Rich Bell	TNC	rich.bell@tnc.org
Jason Boucher	NEFSC	jason.boucher@noaa.gov
Chris Kellogg	NEFMC	ckellog@nefmc.org
Charles Perretti	NEFSC	charles.perretti@noaa.gov

Andy Beet	NEFSC	andrew.beet@noaa.gov
Amanda Hart	UMass Dartmouth	ahart1@umassd.edu
Geret DePiper	NEFSC	geret.depipes@noaa.gov

In addition, there were a number of people participating via conference call, and some that did not register above. The proceedings of the review are detailed in the Review Activities section of this report, starting on page 8.

Appendix 4: List of abbreviations

ABL	Acceptable Biological Limit
Atlantis	Modeling approach and software
B_0	Unfished biomass, a poorly defined reference point
CEFAS	Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK (NMFS' sister organization in England)
Center	NEFSC
Council	NEFMC
CIE	Center for Independent Experts
EBFM	Ecosystem-based fisheries management
EBM	Ecosystem-based management
EDA	Ecosystem Dynamics and Assessment Branch at NEFSC
EMAX	Energy Modeling and Analysis eXercise
EPU	Ecological Production Unit
ESA	Endangered Species Act
ESAM	Extended Stock Assessment Models
EwE	Ecopath with Ecosim (modeling approach and software)
f-ratio	Ratio of new primary production to total primary production
HCR	Harvest Control Rules
HTL	Higher Trophic Levels
LMR	Living Marine Resources
MP	Management Procedures (= MSE)
MSE	Management Strategy Evaluation (= MP)
MSY	Maximum Sustainable Yield
NEFMC	New England Fisheries Management Council (the Council)
NEFSC	Northeast Fisheries Science Center of NOAA/NMFS (the Center)
LTL	Lower trophic levels
NEUS	Northeast U.S. Continental Shelf
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
PDT	NEFMC Plan Development Team for EBFM
PP	Primary productivity
SSB	Spawning Stock Biomass
TE	Trophic transfer efficiency
TL	Trophic Level
ToR	Terms of Reference
VTR	Vessel Trip Reports

EXTERNAL PEER REVIEW OF ECOSYSTEM-BASED FISHERY MANAGEMENT STRATEGY

April 30 – May 3, 2018

Clark Conference Room

NEFSC Woods Hole Laboratory

Woods Hole

MA

Individual Peer Review Report prepared for the Center for Independent Experts

by

Dr. Daniel Howell, Institute of Marine Research, Norway

daniel.howell@hi.no

Table of Contents

Executive summary

Overall the core of the work presented for review, coupling a multispecies “Hydra” model with a Management Strategy Evaluation (MSE) framework, represents a valuable and thorough first step towards a flexible multispecies and mixed fisheries MSE tool. This work has the potential to produce a viable tool for assessing a wide range of potential management strategies, both multi-species management strategies and single species strategies evaluated against a multispecies world. The problems the tool is being asked to solve are focused on mixed fisheries issues, therefore future work should focus on refining the mixed-fisheries abilities of the Hydra model.

This review gives a number of specific technical recommendations for improving the modelling tools, as well as more generic recommendations to guide the approach. The reviewed results represent a work in progress, and several simplifications have been made to get the work moving. This is appropriate given the early stage of this work, but it is important to work on testing (and possibly refining) these simplifications as the model is developed, and critical that a further review be undertaken before the tool be used to guide operational management.

The Harvest Control Rules (HCRs) developed in the work presented for review represent a viable starting set to begin the analysis. It is important that as the HCR set is expanded, care be taken to examine the impacts of making system wide simplifications rather than using detailed species-specific knowledge in setting harvest rates and breakpoints. There are a number of recommendations within this review for specific improvements to the fisheries side of the model, but the main outstanding concern represents the ability of the modelling tool to adequately simulate the proposed management structure. There is a currently major mismatch between the simplified three-fleet structure of the Hydra model and the multiple “fisheries functional groups” (FFG) proposed for management. The proposed management structure is one of setting overall quotas for a number of “fisheries functional groups” (FFGs) covering similar fleet segments targeting a number of different species, with protections included for individual species. Fishers within each FFG could then allocate their overall quota between the species they catch as desired. This is a novel approach, and would need thorough testing, with focus on the degree to which the approach provides protection for individual species within each group. It seems likely that the success or failure of the management will likely hinge on the changing behavior of fishers within each FFG. Therefore, although all models are simplifications, it is critical that the tool be able to simulate the proposed management structure of the fleet. To date, the analysis conducted is rather preliminary, and based on the assumption that the allocation of catches within a FFG will remain the same as in the historical data. This is essentially equivalent to setting species specific quotas, and does not reflect the likely behavior of the fisheries under this scheme. It is critical that the model be used to test out, for example, higher fractions of catch being high value or choke species (e.g., cod) than in the historical split. Given the difficulties in modelling and implementing such a novel approach, it would be valuable to evaluate a wider range of HCRs. As an aside, it should be noted that the multispecies quota implied in the FFG approach does not remove the need for species level stock assessments to monitor the status of the individual stocks.

One of the issues in dealing with managing fisheries in a multispecies context is that it implies choices and trade-offs between species and especially between trophic levels. It should be noted that this issue does not go away under the approach with FFG (or any other Ecosystem Based Fisheries Management [EBFM] scheme). The tool being developed cannot, in itself, address this, but does provide a platform to provide information to decision makers about the impacts of different management scenarios.

The choice of the Georges Bank as a modelling unit (an “Ecosystem Production Unit”, EPU) is reasonable, both *a priori* and based on the analysis presented. However, no finite area will completely contain all species for all of their life cycle. It is therefore important to consider stocks (or fisheries) that cross EPUs in the analysis as the modelling is developed. The modelling has focused on a subset of species in the ecosystem. One could not include all components in a given model, but there are several limitations in the set at present. On the commercial side, it would be valuable to include harvested benthos (scallops, lobsters) in a future analysis. On the ecosystem side, while the current species set represents the majority of the commercial fin-fish catches, it does not include a majority of their food. As a result, the tool is currently better developed to deal with missed fisheries issues than exploring trophic dynamics in the ecosystem.

In terms of the modelling tools, it is encouraging to see two different models (a Kraken production model and a Hydra length structured model) being employed. To date they have been used for different purposes, with the Kraken model being coupled to the portfolio analysis economic simulations, and the Hydra model being coupled to the HCR evaluations. This is a reasonable first step, but the real strength of having multiple models is to compare their results, and it is therefore recommended that the two models be used for both HCR evaluation and the economic analysis. In general, given the "work in progress" nature of this project, there are a number of areas which would benefit from tighter integration of, and comparison between, different parts of the project.

Background

The Ecosystem Based Fishery Management Strategy Review Panel (hereafter referred to as the "Panel") was convened by the New England Fishery Management Council (NEFMC) on April 30 – May 3, 2018 in Woods Hole, MA. The goal of the review was to evaluate a proposed strategy for implementing Ecosystem Based Fishery Management (EBFM) for the New England Fishery Management Council. This was a research-track review, focused on evaluating the conceptual framework of the proposed EBFM strategy and a worked example of its application to the Georges Bank ecosystem. The work reviewed by the Panel was conducted by Northeast Fisheries Science Center (NEFSC) scientists in collaboration with the NEFMC Ecosystem Plan Development Team and with input from the NEFMC. The review included a simulation study to evaluate the appropriateness of the strawman objectives, operating models, assessment models, reference points, harvest control rules, and performance metrics of the EBFM management procedure. The reviewers were asked to provide feedback on the EBFM strategy and to make recommendations that could improve performance of the EBFM strategy. The goal was not to evaluate the output of the EBFM procedure for use in management specification setting at this stage. If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group Overfishing Limits (OFLs), potential changes in management units, etc.

Review Panel

The Panel consisted of Dr. Lisa Kerr (Chair), and Center for Independent Expert reviewers: Dr. Keith Brander, Dr. Villy Christensen, and Dr. Daniel Howell. Dr. Lisa Kerr is currently Vice Chair of the NEFMC Science and Statistical Committee and a research scientist with the Gulf of Maine Research Institute in Portland, Maine. Dr. Keith Brander is a Senior Researcher at Technical University of Denmark, Lyngby Denmark with a background in integrating ecosystem effects into fisheries assessment and management. Dr. Villy Christensen is a Professor at the University of British Columbia specializing in ecosystem modelling. Dr. Daniel Howell is a Fisheries Mathematical Modeller at the Institute of Marine Research in Bergen, Norway, with expertise in multi-species modeling and management strategy evaluation. More information about each panelist's research and scientific expertise can be found at: https://www.nefsc.noaa.gov/program_review/reports2018.html.

As Chair of the Panel, Dr. Kerr facilitated the meeting and made sure that all the terms of reference were reviewed by the Panel. She also led the preparation of the Peer Review Panel Summary Report. Drs. Keith Brander, Villy Christensen, and Daniel Howell served as independent and impartial reviewers. The reviewers each completed independent peer review reports in accordance with the requirements specified in the Statement of Work (Appendix D) and terms of reference (Appendix A), in adherence with the required formatting and content guidelines; reviewers were not required to reach a consensus. Reviewers submitted Individual Peer Review Reports and contributed to the Peer Review Panel Summary Report.

Review Activities

During the review, the NEFMC tasked the Panel with two objectives: 1) review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management

Council (NEFMC), and 2) review the proposed strategy for implementing EBFM on Georges Bank. Under objective two, the Panel was asked to address nine terms of reference (Appendix A):

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

Prior to the in-person meeting, the Panel was provided written materials to review describing the EBFM strategy (Appendix B). During the meeting, the NEFSC EBFM technical team and NEFMC EBFM Plan Development Team (PDT) (including Drs. Mike Fogarty, Rob Gamble, Sean Lucy, Andy Beet, Andy Applegate) presented on model details and results of model simulations under different harvest control rules (see meeting agenda, Appendix B). The review was a public meeting that had several designated times on the agenda for public comment and was open for participation through webinar (Appendix C). All written materials and presentations were made available at the NEFMC website (https://www.nefsc.noaa.gov/program_review/).

Introduction

The review covered several distinct, though, related topics. The review covers both the development of a multispecies and mixed fisheries MSE tool in general, and the specific formulation proposed to deal with the mixed fisheries challenges in the Georges Bank. Therefore, the review must cover both the overall flexibility and power of the MSE tool, as well as how well the mechanics of the MSE tool and associated HCRs match up with the proposed management structure for the fishery; both are critical. These are distinct issues, but cannot be considered in isolation from each other, because the degree of realism required is based on the needs of the other parts of the system. Consequently, designing both the underlying toolbox, and the specifics for the Georges Bank fisheries will require an iterative process.

This review will therefore attempt to address both of the issues discussed above. Since this is a review of work in progress, the review will focus on evaluating if the general approach is sound, and providing both general and specific recommendations on how the work might best be developed. In order to place the HCR approach into a broader global context, the review begins with a brief summary of how the issue of mixed fisheries has been handled in the North Sea. In many ways, this is the closest European parallel to the Georges Bank fisheries.

Global context

The approach described here, of using fishery function groups (FFGs) as the unit of management, is one possible approach to ecosystem management, but it is not the only approach, and other methods are in use or under development around the world. It is valuable to compare this to the somewhat different approach that has been adopted in the North Sea. This review, therefore, gives a brief overview of the North Sea management procedures, in order to highlight the similarities and differences between the two.

The North Sea is co-managed between the EU (under the Common Fisheries Policy) and Norway, and is based on single species quotas. However, the assessment and quota setting procedure incorporates both multispecies (predation) and technical (mixed fisheries) interactions. There is a procedure involving extended single species assessments (mostly using “SAM” Statistical-Catch-At-Age models), a multispecies model to produce predation mortalities (“SMS”), HCRs to translate stock estimates to quota advice, and a mixed fisheries model to assign quotas considering the bycatch in different fleet sectors (“F-cubed”). The procedure is that every three years the multispecies SMS model is run, based on the biomass time series from the assessment models. The SMS model produces time series of partial predation mortalities (M2 values), which are then used in the annual update single species assessments. The annual single species quotas are then fed to the mixed fisheries F-cubed model, which analyses the fishing fleets at a fine scaled “métier” basis in order to try and assign quotas in a way that avoids overfishing bycatch of “choke species”. This procedure is somewhat cumbersome, and there has been initial work towards a closer integration of some of the parts. However, it does provide a coherent structure, in which the SMS model integrates the single species models via predation, and the F-cubed tool essentially conducts a linear programming exercise to allocate quota given the constraints imposed by fleet structure.

Although the mechanics are different, the overall rationale is in many ways similar to the approach presented in this review. The underlying issues, of separate stocks related through predation and extensive technical interactions, are similar. The key difference is that the North Sea sets individual species quotas, and then invests a large amount of effort in allocating these between “métiers”, whereas the work presented here sets quotas for groups of species within a fishing sector, allows the fishers to allocate that overall quota between species as they choose, and then attempts to find ways to protect individual species biomass. This approach clearly sidesteps some of the implementation difficulties, but requires thorough evaluation to be able to foresee the likely outcomes. As the work progresses, it would therefore seem sensible to develop links with the ICES North Sea Working Group to compare approaches and solutions.

Specific comments on each ToR

ToR 1: Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.

The practice of dividing the oceans into manageable scale sectors (such as the EPUs in this work) for modelling and management is a necessary simplification. There are, however, limitations and weaknesses of doing this, notably that some components (fishing and biological) will move between the areas, and it is therefore important to choose area boundaries to minimize these issues. The method chosen, PCA on a range of physical, oceanographic and lower trophic level datasets, seems a reasonable one. Having a hierarchy within each area to account for coastal and shelf break areas is also a good structure, giving flexibility while minimizing complexity. It is reassuring that the PCA analysis corresponds to previous understanding of the spatial structure in the region.

The degree to which a particular EPU description is appropriate cannot be answered in the abstract, but will depend on the use to which it is put. In the present context, this means that an EPU is appropriately defined if it lends itself to simulating and managing the fisheries within that region. The key determinant of how suitable the choice of area structure is likely to be is how well it conforms to the biological and human impact dynamics in the simulation model. It is therefore **recommended** that the spatial structure is refined over time, informed by the modelling studies and other knowledge.

It is also important to be clear that the proposed EBFM structure does not handle well stocks or fisheries that cross EPU boundaries, and this should be made clear when reporting the outcomes of any analysis. It should be noted that these issues are not exclusive to the modelling structure presented here, they exist with current management (so called "straddling stocks" or wide-ranging fisheries), but by imposing a fixed (if broad) spatial structure, the difficulties for advice and management are made more acute. It is therefore likely that if this approach were made operational, then an additional layer of analysis and management to deal with these wide-ranging stocks or fisheries would be required. Consequently, it is **recommended** that there be research into how such cross-EPU stocks or fisheries could be managed under the proposed management schemes.

ToR 2: Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

This review section does not deal with the specifics of the lower trophic level energy flow model, as this reviewer has limited experience on this topic. Rather the text will focus on the uncertainties and how they impact on the overall results of the management strategy evaluation.

The question of "is the model fit for purpose" depends largely on what the intended purpose is. If it is providing numerical input into the fisheries operating model or to provide absolute estimates of reference points, then the model would need further development and verification before it could be used. On the other hand, the modelling tool would be much more suitable for giving a qualitative understanding of trends or providing order-of-magnitude values for "sanity checking" other models. There is a mis-match issue where the estimation methods are based on harvesting the whole system, with some defined split between trophic levels. In practice, fisheries will target only a fraction of the available fish stocks, and the overall trophic level of the fisheries may differ from those used in the calculations.

The uncertainty range of the outputs is rather large. This is not surprising given the difficulties of modelling lower trophic levels and energy transfer. The model can therefore be used to give "order-of-magnitude" style results to compare against overall fishing, and for describing trends in overall productivity, but exact estimates should be used with care. It is **recommended** that care be taken to ensure that this uncertainty is made clear, not just when presenting the details of the work, but also in the headline results. This is not done consistently within the review document. For example, table 2.1 of the review document gives detailed uncertainty estimates, but the discussion session simply quotes point estimates. It would seem likely that as the results are used in more distant contexts (e.g., management summaries), more of the uncertainty information would get lost. It is therefore critical that whenever point estimates are quoted, the uncertainty estimates are included.

It is **recommended** to compare the results with those from other approaches (e.g., Ecopath) available in the area. There will be differences involved, depending on exactly what is being compared (e.g., "fish stocks" vs. "fished stocks"), but it should be possible to make the model outputs comparable and give bounds on uncertainty ranges.

It is not clear to this reviewer how such an approach can set limits for ecosystem removal in the context of proposed changing fisheries patterns, both by trophic level and what fraction of the ecosystem. Acceptable total removals will vary with the average trophic level of the catch, so it is difficult to see how this can form a fixed limit to system removals.

ToR 3: Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

The rationale of the fishery functional groups combines fish caught in similar fleets, grouping within feeding guilds, and life history traits. Combining fishing and biology in this way at this scale is a novel approach to fisheries management. In principle, this provides a good mix between fisheries and biological traits. It maps the groups to manageable fishery units, as well as considering ecosystem function and avoids grouping very dissimilar species. Note that it is important to also consider the individual species within each group, and monitor the status of the different species.

One would note that the patterns of catches between different fisheries may not be constant over time. These changes may arise spontaneously from changing biology or fisher behavior, or could arise in response to specific management action to influence fishing patterns. Consequently, the behavior of FFGs should not be considered constant over time. Both the behavior within each FFG, and the relationship between them, is likely to vary over time. Considering the boundaries between FFGs, it should not be expected that these will be fixed over time either. Rather, the definition of FFGs will likely vary with changing social, environmental, biological and management environments. Within each FFG, the model will, of necessity, have been conditioned on historical fishing patterns, but if the fishermen are given quotas for a group of species, they are likely to change their fishing pattern, targeting various species to different degrees than in the historical fishing. Such changed fishing patterns would reduce the applicability of the modelling studies conducted without accounting for this. It is **strongly recommended** that extensive effort be placed on evaluating the impacts on management performance of such changes in fisher behavior. This reviewer considers that *without such investigations the simulation tool cannot be considered suitable for investigating grouped FFG-based quotas.*

ToR 4: Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

The overall approach is sound, producing a tentative list of objectives and performance metrics. However, in the discussion, it was notable that the list of objectives was described as not being complete (specifically in relation to the use, or not, of F reference points for target species). Furthermore, the applicability of different metrics is something that will need to be tested during the development of the modelling approach. It is therefore not feasible to evaluate the appropriateness of the list of objectives and performance metrics, as requested by the ToR. Rather, the review can state that the approach of building out from the initial set provided is appropriate, and give recommendations to guide further development.

The overall set of strategic objectives is reasonable, but a more detailed list of operational objectives is required. The success or failure of the objectives will depend on the method of quantifying the details within each category, and the metrics which are chosen. One key concern is that the only metric of reduced single species stock status is being reduced below 20% of unfished biomass (Blim). This gives information on reduced stock reproduction potential, but does not give information on reduced yield potential. It is **strongly recommended** that all results also report the fraction of stocks falling below the higher trigger point at which fishing is reduced (e.g., the current Btrigger set as 40% of unfished biomass). Such a trigger may or may not be included in the HCRs, but should always be a performance metric. More generally, as work proceeds it is **recommended** that the utility of the different metrics is evaluated and refined as the work proceeds.

ToR 5: Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

Once again, the utility of the management reference points is difficult to evaluate without knowing the more general management structures and results of the final simulation analysis.

For the overall removal cap, it not clear what purpose this serves. According to the presentations, it was unlikely that this could be achieved in practice, and a separate analysis presented at the review (by Amanda Hart) indicated that at moderate to high levels, the choice of value of the removal cap had little impact on the management.

The reference points at the FFG and single species levels do serve a clear purpose, and the simplified generic values (e.g., 20% of unfished biomass) used in this study are adequate for an initial exploratory analysis such as this, but it is **strongly recommended** that they be replaced with species-specific reference points before the system becomes operational. Furthermore, it is not clear how the ceiling on removals at the FFG level would be quantified for actual fisheries. The fraction of unfished biomass is both appropriate and easy to calculate in a simulation framework, but may be neither in an operational setting. Before moving to operational management, care is needed to ensure that the reference points are appropriate to each species (and, in sexually dimorphic species it may need gender specific reference points), and to move to more realistic limit points.

One concern is that the only species-specific reference points are biomass floors, and these are likely substantially lower than current Bmsy targets (the proposed limits are more analogous to precautionary fishing avoiding recruitment overfishing). Given the reference point set proposed, a fishing strategy could be counted as "successful" even though it resulted in a number of the key species (for example, cod) being fished consistently to a level only slightly above the biomass floors. This is likely to result in reduced yield of these species, and it is an open question if this would be acceptable. This problem is largely avoided by use of a higher trigger biomass below which fishing is reduced (set at 40% of unfished in the examples here). Regardless of whether these higher trigger points in the HCR (below) are used in a given simulation, it is **recommended** that the fraction of stocks below this Btrigger value be used as a reference point for single species status (reflecting reduced yield potential rather than reduced recruitment potential).

Note that the simulation model can evaluate if any reference points are breached, but the presentations seem to indicate that the only action being taken in the model simulations at present are dropping below floors. It appears as if there is no current capability to adjust fishing within each FFG if the ceilings are breached, and the current HCRs do not seem written to take this into account. If this is the case, then model development may be required to address this.

ToR 6: Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points

The HCRs put forward at the review represent an initial attempt at a suite of candidate rules to be able to conduct initial simulations and inform future discussions. In this context, the HCRs can be said to fulfil the ToR, covering a range of different management measures to protect fish stocks at different degrees of aggregation. One would expect that this suite of HCRs would be expanded and refined as the approach is developed.

The HCRs implement both a threshold level below which landings are not permitted (and catches set to some levels), and potentially a higher (Btrigger) level below which exploitation is linearly reduced. For the initial runs these were set at 20% and 40% of the unfished biomass. As the approach is developed more fully, one would expect that alternative reference points would be evaluated, including some using best available science for the individual species. The full suite (the floor and the high level) approximates to a traditional MSY "hockey stick" HCR, while simply using the lower floor level corresponds to an "avoid recruitment overfishing" precautionary approach. Any choice to move between these two approaches is independent of any move to EBFM. It is therefore **recommended** that if there is a proposal to remove this higher Btrigger value, the implications of this be thoroughly investigated.

The work has been phrased as an academic exercise, without reference to operational management procedures. At the current stage this is a valid approach, providing a semi-concrete example to spur further discussion. However, it is important to note that there must be an interaction between the management structures and the simulation studies, where management must be informed by what is scientifically feasible and where the scientific work must fit into the management requirements. In this context, the work presented here represents a valuable first step in an iterative process.

The work to date has incorporated step-wise reductions in fishing below a Btrigger value. This is acceptable in a simulation environment, but is likely to prove problematic in an operational setting. Such discrete steps give rise to situations where small changes in assessment produce large changes in quotas, which places a high stress on the reliability of the assessment and can lead to implementation difficulties. It is therefore **strongly recommended** that the step functions within the HCRs be replaced with smooth ramps before this work gets closer to operational management.

The HCRs examined to date have been exclusively phrased around grouped FFG quotas. This is not a requirement for EBFM, and the system being developed is able to evaluate a wider range of HCRs, including evaluating single species quotas against a multispecies reality. It is therefore recommended that the system be used to evaluate the performance of single species HCRs against the grouped FFG quota ones. Furthermore, there need not be a binary distinction between these two regimes, and there may well be large gains to be made by moving to grouped quotas for some but not all species. It is therefore **strongly recommended** that hybrid HCRs be evaluated, where in addition to overall quotas for a fishery group there is a more specific constraint on one (or several) key species. For example, a rule of the form “X tonnes of quota, but no more than Y of it can be of species Z”.

ToR 7: Review the structure and application of operating models for Georges Bank.

The approach of using two structurally distinct Operating Models (OMs) is a good one. The Hydra model is, in principle, a good tool for use as an OM, combining detail and potential realism with moderate run times. As the model is still under development, this section outlines the main areas of remaining work, and gives recommendations for improvements.

There are two issues that are of most concern with outstanding issues with development of the Hydra OM. One is the need for evaluating the model against real world historical observations in order to demonstrate that the model can produce credible results. One would not expect such a model, without optimization to annual recruitment deviations, to track actual stock history. However, it would be reasonable to expect that stock dynamics, stock biomasses, and catches under approximations to historic fishing conditions should approximate to historic observation. For example, putting catches of similar levels to those which resulted in stock declines in the 1970s should result in stock declines in the model, while catches similar to those in the 2000s should keep the modelled stocks roughly stable. The second outstanding issue is the need to evaluate the fleet structure against the requirements of evaluating the proposed management actions. For example, testing the robustness of the proposed FFG quotas would need to involve simulating the effects of changing species catchabilities within the fleet. The model must therefore be able to simulate this, and it is not clear that the structure is currently capable of doing this. It is not necessary that the model completely matches the “real world”, but it may be necessary to increase the level of detail in the fishing model in order to realistically evaluate the fisheries. It is therefore **strongly recommended** that as the modelling develops, work is focused on ensuring that the model is able to model the fishing dynamics of importance for the HCRs being evaluated. Additionally, the current fishing selectivities are all flat topped logistic curves, which may not well model some of the fisheries. It is **recommended** to investigate allowing dome shaped selectivity in the OM, especially if the fleet structure is made more detailed than at present.

One issue which arises within any multispecies model is the extent to which the results are sensitive to the amount of “otherfood” (i.e., external to the model). Ideally, the key food components for critical species within the model should all be fully modelled. If this is not possible, then care should be taken with the external “otherfood”, giving as much realism as possible and checking for model sensitivity to this input. As “otherfood” is typically not well specified, it is **recommended** to investigate the sensitivity of the model to this parameter.

The approach of having a family of recruit curves is interesting, and represents a possible way to model recruitment uncertainty. However, it was concerning that all the additional curves were to the left of the fitted function – this gives additional ability to recover from poor stock size beyond that implied by the data. This raises the possibility that the model could add spurious robustness to some stocks. If this approach is pursued, then it is **recommended** that using families of recruitment curves that are symmetrically distributed around the fitted function is investigated. It seems likely that the families of recruitment functions are being investigated in order to compensate for the functional forms of the interannual variability (“noise”) being unable to handle species with sporadic recruitment, and it is likely that this could be better achieved by adjusting the functional form. The “noise” on the recruitment functions are currently lognormal. This is likely to be too restrictive for some stocks, and it is **recommended** that this be expanded. For those with erratic recruitment (e.g., haddock or herring), a joint distribution method might be preferable, with the majority of year-classes being drawn from one distribution, and a minority being drawn from a second distribution. For some stocks it might be necessary to include the possibility of having runs of good or bad recruitment. This could be modelled simply by applying a sin-curve multiplier to the recruitment success, or more realistically as a Markovian process.

At present the overfished metric tracks the fraction of time spent in a depleted state. This is problematic as it is influenced by the recruitment at low stock sizes, and this part of the function is typically poorly constrained by data. A simpler metric, just counting how many stocks crash at least once in any given 10-year reporting period, would avoid this uncertainty. It is therefore **recommended** that the overfished metric be changed to the simpler version tracking how many stocks crash at least once within a reporting period. It can be noted that this would also be consistent with the ICES approach.

ToR 8: Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

At present, the system uses simple "truth plus specified cv noise" for assessment. This is one possible approach, which is used in many actual MSE exercises, and it aids in rapidly building a working model. There was work presented on using multispecies assessments, although this was not integrated into final the HYDRA model simulations presented. A range of methods were presented (index, production model, delay-difference model), which gives the possibility to produce reasonable assessments for a range of stocks. However, these methods do not replicate well the existing assessment methods, and it is not clear why they are being used instead of single species assessments. Single species assessments would be both easier to implement, and better match the actual management systems being simulated. Furthermore, while the Hydra tool is suitable for testing new assessment methods (e.g. multispecies assessments), this should be kept separate from testing new HCRs (e.g., ones based on FFGs).

It is **recommended** that care be taken to ensure that the assessments replicate the error structure seen in the actual assessments used in management. This could be done by replicating the existing single species assessment methods (full assessment and index-based), or by approximating these with defined error structures, either in multispecies or "truth plus noise" assessments.

It is **strongly recommended** that the model not be used to evaluate new assessment methods and new HCRs simultaneously, as this would make it difficult to evaluate what was causing any successes or failures in the simulated management. This should not be taken to argue against evaluating either, merely that they be evaluated separately.

ToR 9: Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

Given the preliminary state of the work, the simulation work is rather limited. The scenarios run have been designed around the proposed management structure, but cannot at this stage be said to fully evaluate the management. However, the simulations conducted do begin to test out the management proposals, and can be considered to represent a good starting set which will be developed in parallel with model development.

The major limitation in the simulations conducted to date is that the model fleet structure does not simulate well the proposed management structure, and thus further model development is required to be able to realistically model the proposed structure. As the model is developed and refined in this regard, the set of simulations will need to develop in parallel.

It was clear during the review that the work was at an early stage, with a number of the graphs being difficult to interpret (for example some, but not all, vertical axes on the stock trends graphs starting at zero). It is anticipated that the graphs presented will evolve as the work proceeds.

A point of confusion arose from the presentations on the simulations, where it appeared as if a fixed exploitation rate was being applied across multiple species. Further discussions identified that this is not the case. A flat multiplier was being applied (at different levels), but this was multiplied by species specific catchability rates. It is critical that this distinction be made clear in future reports and presentations, and that realized fishing pressure on each stock be reported.

Given the limitations described in this section, the preliminary simulations do begin to address the performance of the modelling system, and begin to show interesting results. The absolute levels of catches are broadly in line with historical ones, suggesting a degree of realism in the proposed fishing pressures. For example, the HCRs which included "hockey stick" style reductions in fishing below some biomass trigger (but above the biomass floor) performed better than HCRs without this precautionarity.

Specific recommendations for future work

The current metric of "overfished" status measures the fraction of years the stocks are below a reference level. This is a valid metric, but has the unfortunate implication that the fraction of time a stock spends in a deplete state becomes sensitive to the recruitment at low stock size (how fast the stock recovers from overfishing). A significant amount of effort has been placed on this part of the stock-recruitment function during model development, but it remains highly uncertain. It is therefore **recommended** that a simple metric, just counting how many stocks crash at least once in any given 10-year reporting period be investigated. This is an ICES standard, and largely avoids having an overfishing metric being sensitive to the most uncertain part of the recruitment function.

It is **recommended** that realized F, and the ratio of realized F/nominal F be investigated as metrics. This would give better information on what fishing pressures were actually applied (which is difficult to determine from the results presented to date). These (and especially the ratio) would help identify the degree to which catch in a given FFG was being reduced by the single species protections within the HCRs.

As discussed in previous sections, simulations that address the behavior of fishers within each FFG (for example, switching fishing pressure between species) are **strongly recommended**. In order to do this, the modelled fleet structure will need to be further developed. At present the model could change to something like "the fraction of cod in the trawl fleet catches", but not "the fraction of cod in the catches of FFG7".

There is clear potential to parallelize the model runs. Since many simulations are required, each simulation can be assigned to a given thread or processor. This makes the parallelization process both simple and effective, and it is r**ecommended** that this be developed.

It is **recommended** that simulations be conducted examining the difference between system-wide limits (e.g., 20% of unfished biomass) and species-specific ones (e.g., using the reference point from the assessment).

It is **recommended** that a wider range of selectivities (e.g., dome shaped) be included in the simulations, to best replicate actual fishing patterns.

More generally, wherever there is a simplification (e.g., thresholds, trigger points, global exploitation rates, FFG structure) in the model, it is **recommended** that the effects of adding realism are investigated for each simplification separately. It may be that some of the current simplifications are justified, increasing speed and robustness without harming accuracy, but this needs to be tested.

It is **recommended** that "sanity checks" are applied to different levels within the model (stock size, species removals, group removals, …). The aim would be to rapidly identify anything which is outside the realistic range (based on historical knowledge). This is important, as an unrealistic biomass in one species within the model may impact on the reliability of results from other species.

APPENDIX A

Final Terms of Reference
Ecosystem Based Fishery Management Strategy Review
April 30-May 3, 2018
NOAA Fisheries/Clark Conference Room
Woods Hole MA

Objective 1
Review a proposed implementation of Ecosystem Based Fishery Management for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the New England Fishery Management Council. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC strawman management objectives as well as evaluate a worked example intended to simulate the performance of the EBFM procedure. (The strawman objectives were used to develop the EBFM strategy and framework; final objectives will be developed and approved by the NEFMC at a later date.)

The reviewers will be asked to provide recommendations that could improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a SAW/SARC assessment review).

The review will encompass the EBFM procedure, the potential operating models used to test the procedure, and a worked example of the relative performance of the EBFM procedure for providing quota advice as they pertain to fisheries management of Georges Bank fisheries.

If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: definition of management objectives by the NEFMC, potential changes in regulations and fishery management plans, clarification from NMFS on the application of functional group OFLs, potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Objective 2
Review the proposed strategy for implementing EBFM on Georges Bank

Terms of Reference

1) Evaluate the approach used to identify Ecological Production Units on the Northeast Shelf of the United States and the strengths and weaknesses of using these Ecological Production Units as the spatial footprint for Ecosystem Based Fisheries Management in the region.
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2) Evaluate the methods for estimating ecosystem productivity for the Georges Bank Ecological Production Unit and advise on the suitability of the above methods for defining limits on ecosystem removals as part of a management procedure.

3) Evaluate the approach and rationale for specifying Fishery Functional Groups as proposed management units.

4) Comment on the applicability and utility of the strawman management objectives and associated performance metrics which were used to guide the development of operating models.

5) Evaluate the utility of the proposed management reference points as part of a management control rule for ecosystem-based fishery management. These include: an overall catch cap at the Ecological Production Unit level conditioned on environmental conditions, ceilings on catch for each Fishery Functional Group (defining overfishing) conditioned on aggregate properties, and biomass floors at the single species level (defining overfished conditions).

6) Review harvest control rules embodying the proposed floors and ceilings approach using the ceiling reference points in ToR 5 to cap removals at the Ecological Production Unit and Functional Group levels, while ensuring that no species biomass falls below the single species floor reference points.

7) Review the structure and application of operating models for Georges Bank.

8) Review ecosystem assessment models and required data sources, as applied to the simulated data from the operating models in ToR 7.

9) Review simulation tests and performance of the proposed management procedure incorporating the floors and ceilings approach, given the set of EBFM goals and objectives.

APPENDIX B

Agenda, Documentation, and Presentations for 2018 Ecosystem Based Fishery Management (EBFM) Strategy Review

Documents for Review

The main document provided for reviewed by the Panel was an overview of the EBFM management procedure:

NEFSC Fishery Ecosystem Dynamics Assessment Branch. 2018. Ecosystem-Based Fishery Management Strategy, Georges Bank Prototype Study. Summary Document. April 20-May 2, 2018, Woods Hole, MA. https://www.nefsc.noaa.gov/program_review/docs/Georges%20Bank%20EBFM%20Summary%20Document.pdf.

In addition, the following background materials were reviewed by the Panel:

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for Prototype Georges Bank, Fishery Ecosystem Plan. Catch Advice Framework, a Worked Example #2. New England Fishery Management Council. September 26-28, 2017. http://s3.amazonaws.com/nefmc.org/2_A-Framework-for-Proividing-Catch-Advice-for-a-Prototype-Georges-Bank-FEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. A Framework for Providing Catch Advice for a Fishery Ecosystem Plan (FEP). New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf.

Ecosystem Based Fishery Management PDT. 2017. DRAFT: Example application of operation models for Georges Bank ecosystem production unit (EPU) strategy evaluation. New England Fishery Management Council. January 2017. http://s3.amazonaws.com/nefmc.org/Document-3.-Example-application-of-operating-models-for-Georges-Bank-ecosystem.pdf.

Fogarty, M. J., Overholtz, W. J., Link, J. S. 2012. Aggregate surplus production models for demersal fisher resources of the Gulf of Maine. Marine Ecology Progress Series, 459:247-258. https://www.nefsc.noaa.gov/program_review/docs/b4-fogarty%20et%20al%20MEPS.pdf.

Gaichas, S., Gamble, R., Fogarty, M., Benoît, H., Essington, T., Fu, C., Koen-Alonso, M., Link., J. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Marine Ecology Progress Series, 459:275-292. https://www.nefsc.noaa.gov/program_review/docs/b5-Gaichas%20et%20al%20MEPS.pdf.

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Hennemuth, R. C., Rothschild, B. J., Anderson, L. G., Kund, Jr., W. A. 1980. Overview Document of the Northeast Fisher Management Task Force, Phase 1. NOAA Technical Memorandum NMFS-F/NEC-1. October 1980. https://www.nefsc.noaa.gov/program_review/docs/b3-tm-1-hennemuith.pdf.

Link, J. S., Gamble, R. J., Fogarty, M. J. 2011. An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management. Northeast Fisheries Science Center Reference Document 11-23. October 2011. https://www.nefsc.noaa.gov/program_review/docs/b2-crd-1123.pdf.

Lucey, S. M., Cook, A. M., Boldt, J. L., Link, J. S., Essington, T. E., Miller, T. J. 2012. Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems. Marine Ecology Progress Series, 469:219-229. https://www.nefsc.noaa.gov/program_review/docs/b-7Lucey%20et%20al%20MEPS.pdf.

NEFMC Scientific and Statistical Committee. 2010. White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council. October 2010. https://www.nefsc.noaa.gov/program_review/docs/b1NEFMC%20EBFM%20White%20Paper_report_15%20oct%202010.pdf.

Presentations for Review

Presentations that covered the following topics were reviewed by the Panel during the in-person meeting:

1. Objectives for the Review (Mike Simpkins, NEFSC)

2. Logistics (Rob Gamble, NEFSC)

3. NEFMC Ecosystem-Based Fisheries Management Plan Development Team (Andrew Applegate, NEFMC)

4. Background and Overview of Proposed Management Procedure (Mike Fogarty, NEFSC)

5. Defining Ecological Production Units (Robert Gamble, NEFSC)

6. Ecosystem Production Potential (Michael Fogarty, NEFSC and Kimberly Hyde, NEFSC)

7. Defining Fisheries Functional Groups (Sean Lucey, NEFSC and Mike Fogarty, NEFSC)

8. Strawman Management Objectives and Performance Metrics (Richard Bell, The Nature Conservancy)

9. Ecosystem-Based Reference Points (Mike Fogarty, NEFSC)

10. Harvest Control Rules (Mike Fogarty, NEFSC)

11. Structure and Application of Operating Models -- Part 2 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

12. Structure and Application of Operating Models --Part 2 Kraken (Robert Gamble, NEFSC and Geret DePiper, NEFSC)

13. Structure and Application of Assessment Models (Charles Perretti, NEFSC and Mike Fogarty, NEFSC)

14. Simulation Tests and Performance Management Procedure -- Part 1 Hydra (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

15. Simulation Tests and Performance Management Procedure -- Part 2 Kraken (Andy Beet, NEFSC and Mike Fogarty, NEFSC)

Agenda for Review

Date	***Time***	***Topic and Related Documents***	***Presenter/Lead***	***Theme Area***
Monday April 30	9:00 AM	**Welcome and Objectives for the Review** Background Documents **Ecosystem-Based Fishery Management Strategy Georges Bank Prototype Study Summary Document** **White paper on Ecosystem-Based Fishery Management for New England Fishery Management Council (2010)** **An Overview of the NEFSC's Ecosystem Modeling Enterprise for the Northeast US Shelf Large Marine Ecosystem: Towards Ecosystem-based Fisheries Management** **Overview of the Northeast Fishery Management Task Force Phase 1 (1980)** **Aggregate surplus production models for demersal fishery resources of the Gulf of Maine** **Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation** **Using an aggregate production simulation model with ecological interactions to explore effects of fishing and climate on a fish community** **Comparative analyses of surplus production dynamics of functional feeding groups across 12 northern hemisphere marine ecosystems**	Jon Hare *NEFSC Science and Research Director* Mike Simpkins *Resource Evaluation and Assessment Division Chief*	
	9:15 AM	**Logistics**	Robert Gamble, NEFSC	
	9:30 AM	**NEFMC Ecosystem-Based Fisheries Management Plan Development Team** Background Documents **A Framework for Providing Catch Advice for a Prototype Georges Bank Fishery Ecosystem Plan** **A Framework for Providing Catch Advice For a Fishery Ecosystem Plan** **DRAFT: Example application of operating models for Georges Bank ecosystem production unit (EPU) strategy evaluation**	**Andrew Applegate**, NEFMC	
	10:00 AM	**Background and Overview of Proposed Management Procedure**	**Michael Fogarty**, NEFSC	
	10:30 Break			
	11:00 AM	**Defining Ecological Production Units**	**Robert Gamble**, NEFSC	TOR 1
	11:30 AM	**Ecosystem Production Potential**	**Michael Fogarty**, NEFSC Kimberly Hyde, NEFSC	TOR 2
	12:00 Lunch			
	1:30	**Defining Fishery Functional Groups**	**Sean Lucey**, NEFSC	TOR 3

	PM		Mike Fogarty, NEFSC	
	2:00 PM	**Strawman Management Objectives and Performance Metrics**	Richard Bell The Nature Conservancy	TOR 4
	2:30 PM	**Ecosystem-Based Reference Points**	Michael Fogarty, NEFSC	TOR 5
		3:00 Break		
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Tuesday May 1	9:00 AM	**Harvest Control Rules**	Mike Fogarty, NEFSC	TOR 6
	9:30 AM	**Structure and Application of Operating Models -- Part 1 Hydra**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 7
		10:30 Break		
	11:00 AM	**Structure and Application of Operating Models -- Part 2 Kraken**	Robert Gamble, NEFSC Geret DePiper, NEFSC	TOR 7
		12:00 Lunch		
	1:30 PM	**Structure and Application of Assessment Models**	Mike Fogarty, NEFSC	TOR 8
	2:00 PM	**Simulation Tests and Performance Management Procedure -- Part 1 Hydra**	Andy Beet, NEFSC Michael Fogarty, NEFSC	TOR 9
		3:00 PM Break		
	3:30 PM	**Open Question Period**		
	4:30 PM	**Public Comment Period**		
	5:00 PM	**Review Panel Discussion (private)**		
Wednesday May 2	9:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 1 Hydra, continued**	Andy Beet, NEFSC Mike Fogarty, NEFSC	TOR 9
	10:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken**	Amanda Hart, UMASS Dartmouth Geret Depiper, NEFSC Robert Gamble, NEFSC	TOR 9
		10:30 Break		
	11:00 AM	**Simulation Tests and Performance of Management Procedure -- Part 2 Kraken,continued**	Geret Depiper, NEFSC Robert Gamble, NEFSC Amanda Hart, UMASS Dartmouth	TOR 9
		12:00 Lunch		
	1:30 PM	**Open Question Period**		
		3:00 PM Break		
	3:30	**Public Comment Period**		

	PM			
	4:30 PM	**Review Panel Discussion (private)**		
Thursday May 3	9:00 AM	**Review Panel Report Writing (private)**		

APPENDIX C

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APPENDIX D

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Ecosystem Based Fishery Management Strategy Review

Background
The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope
Ecosystem Based Fishery Management (EBFM) Strategy Review

Objective: Review a proposed implementation of EBFM for the New England Fishery Management Council (NEFMC).

The review is essentially a research-track review, the goal of which is to illustrate how the proposed EBFM strategy and conceptual framework would be applied to provide the information needed for fisheries management by the NEFMC. The review will focus on the management procedure performance relative to a specified set of metrics related to NEFMC management objectives, as well as evaluate an "operating model" intended to simulate the performance of the EBFM procedure. The "operating model" in this case is a multi-model suite that can include empirical approaches as well as simulation models. The reviewers will be asked to provide recommendations to improve EBFM strategy performance, as well as potential data inputs, operating model structures, and performance metrics. The goal is not to evaluate output of the procedure for use in specification setting (e.g., this is not a Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) review process).

The review will encompass the EBFM procedure, the suite of operating models, and a worked example of quota advice as they pertain to fisheries management in the Northeast region.
If the review is favorable, subsequent steps will be necessary before the procedure can be used in specification setting. These subsequent steps include: potential changes in regulations and fishery

management plans, clarification from NMFS on the application of functional group Overfishing Limits (OFLs), potential changes in management units, etc. The identification of the management changes needed to use the model results are not part of the review.

Reviewer Requirements
NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the SOW, OMB Guidelines, and the TORs below. The reviewers should have working knowledge and recent experience in ecosystem-based fishery management particularly in areas of Management Strategy Evaluation/Management Procedures, Fishery Ecosystem Plans, Integrated Ecosystem Assessments, ecosystem models, multi-species models, population dynamics, harvest strategies, and fisheries management regulations as they apply to EBFM. We prefer having at least one international reviewer and at least one reviewer from the U.S. The third reviewer can be an international or U.S reviewer.

Tasks for Reviewers
- Review background materials and reports prior to the review meeting related to the Terms of Reference.
- Attend and participate in the panel review meeting
    - The meeting will consist of presentations by NOAA and other scientists, and other experts to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
- Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance
When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at Northeast Fisheries Science Center Woods Hole, MA

Period of Performance
The period of performance shall be from the time of award through March 2018. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
April/May 2017	Panel review meeting
Approximately 3 weeks later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards
The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each ToR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel
All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $12,000.

Restricted or Limited Use of Data
The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact:
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Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.
b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.
c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.
d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.
e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review
Appendix 2: A copy of this Statement of Work
Appendix 3: Panel membership or other pertinent information from the panel review meeting.